LISA – Preventivi 2025

Rita Dolesi

Coordinatore Nazionale

Principali eventi del progetto LISA nel 2024-25

- **L'adozione di LISA, come "Large Mission" del programma ESA Cosmic Vision, è stata confermata dal voto dello Science Program Committee di ESA in data 25 gennaio 2024, con previsione di una fase di implementazione di 11 anni, per un lancio entro fine 2035.**
- A fine marzo 2024, ESA ha emesso il bando della gara di appalto **– LISA System Prime ITT**. La fase B2 dovrebbe durare circa 3 anni e finire con la Preliminary Design Review al livello di missione per l'inizio di 2028**. Il vincitore della gara è OHB Bremen, con un forte contributo della Thales Alenia Spazio di Torino** con cui è già iniziata l'attività di co-engineering.
- Firma del **"ESA/SPC Multilateral Agreement concerning the LISA mission"**, che ha definito i termini e le condizioni che governeranno le relazioni di ESA con i partner riguardo ai contributi a LISA, distinti in: Contributi al Payload Scientifico e Contributi al Science Ground Segment.
- A riguardo di quest'ultimo, **il Distributed Data Processing Center (DDPC),** responsabile dello sviluppo delle pipeline di analisi che porteranno alla produzione di cataloghi di sorgenti e prodotti annessi a partire dai dati grezzi, ha ufficialmente iniziato le proprie attività con un meeting di tre giorni a Tolosa nel Giugno 2024 **L'Italia ha assunto un ruolo centrale, coprendo posizioni di leadership in diverse di queste Coordination Unit e nel Project Office**. E' stato avviato un dialogo con le comunità di VIRGO ed ET e delineate possibili sinergie su tematiche di analisi dati che costituirebbero un'opportunità di metter a fattor comune risorse umane e competenze, per un rafforzamento dell'impatto e delle prospettive di sviluppo della comunità sul lungo periodo, e del conseguente ritorno scientifico;

- In **autunno 2024 si è completata, con successo, una prima "Performance Review**", condotta come review interno di ESA sulla performance di LISA. L'obiettivo era di verificare la coerenza del performance budge conl'albero completo dei requisiti. Pur sottolineando la necessità di indagare effetti che sfuggono al modello, la review ha avuto esito positivo, con la completezza e coerenza del performance budget considerato molto maturo per questa fase della missione e una base solida da cui partire con la fase B2.

La collaborazione italiana ha fornito a tutto il processo di review un supporto tecnico e programmatico rilevante, producendo estesa documentazione, note tecniche con analisi e simulazioni specifiche, e supportando innumerevoli progress meeting e telecon con le agenzie spaziali e il partner industriale italiano OHB Italia.

- **In corso in questi giorni la PDR del Gravitational Reference Sensor**

Principali eventi del progetto LISA nel 2024-25

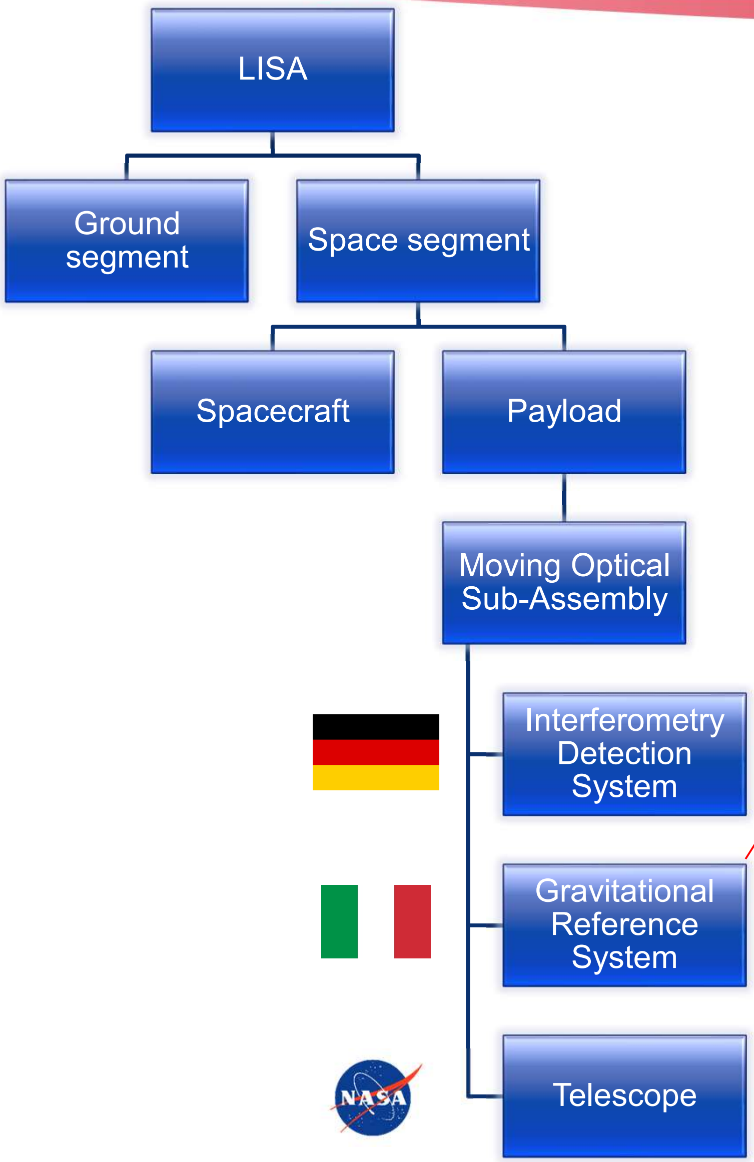
- **Il Nuovo Accordo Attuativo dell'Accordo Quadro ASI/Università di Trento n. 2017-32-H.0 per "Attività per la fase B2/C della missione LISA"** è diventato operativo nel settembre 2024 per una durata di 39 mesi. L'oggetto di tale accordo sono le attività previste per il team scientifico italiano durante la fase B2/C della missione ESA LISA.
- Ai WP dell'accordo precedente che **coinvolgevano INFN, in questo nuovo accordo si è aggiunto il nuovo WP "Support to GRS avionics development" del gruppo INFN di Roma II, che entra così nelle attività del GRS PI Team.**
- Nel gruppo di Roma II è stato avviato inoltre un nucleo di attività nell'ambito dello Science Ground Segment in sinergia con gli altri gruppi italiani attivi già da alcuni anni su questo fronte. Quest'attività, insieme a quelle portate avanti dal gruppo di Firenze-Urbino che riguardano lo studio e la simulazione del processo di carica delle masse di prova di LISA a causa dell'interazione dell'intero satellite con i raggi cosmici e le particelle solari di alta energia, sono oggetto di **nuovi WPs nell'addendum all'accordo ASI attualmente in preparazione.**
- Nell'ambito del nuovo accordo proseguiranno naturalmente le attività legate alla fornitura hardware di responsabilità italiana, il Gravitational Reference System, in cui un ruolo cruciale svolto con il supporto INFN riguarda la preparazione delle facilty di test a terra e l'esecuzione nel 2026-2027 del piano di verifiche previsto per l'Engineering Model del sensore capacitivo, cuore del GRS, e del sistema di rilascio delle test mass in volo con il Grabbing, Positioning and Releasing System (GPRS).
- Riguardo alla proposta della White House di tagliare alla NASA i fondi per LISA,il messaggio circolato dal PM ESA di LISA è il seguente:

"….LISA è il fiore all'occhiello dell'ESA **e l'Agenzia ha adottato le misure necessarie per gestire il rischio di interruzione del contributo della NASA, in stretto coordinamento con gli Stati membri.**

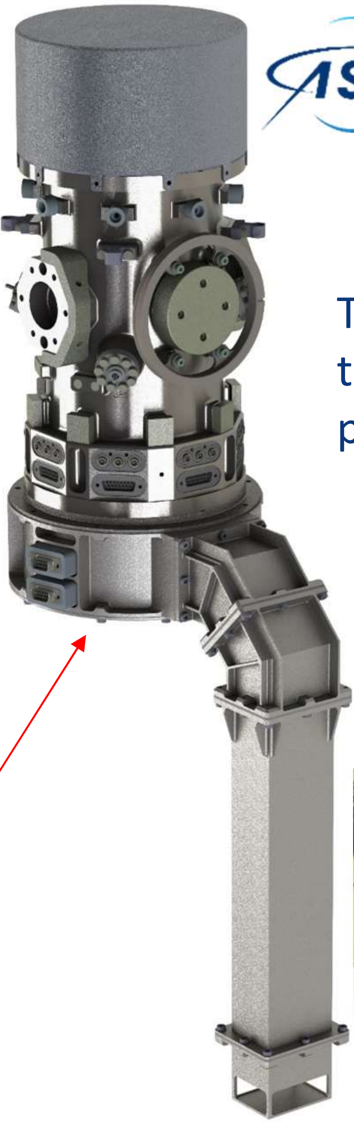
Ci vorrà un po' di tempo per capire dove si stanno realmente dirigendo gli Stati Uniti e se e come verrà attuato il piano di mitigazione.

Fino ad allora, è di fondamentale importanza lavorare per raggiungere i nostri obiettivi prefissati, ad esempio il System SRR, il GRS PDR, il IDS PDR eccetera, e continuare a dimostrare gli ottimi progressi compiuti finora dall'adozione della missione."

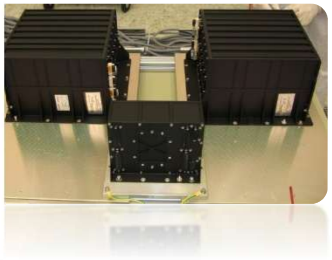
LISA Product Breakdown (notional)

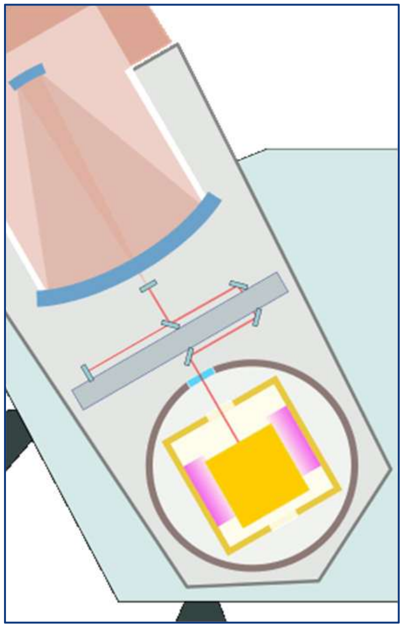


- LISA
  - Ground segment
  - Space segment
    - Spacecraft
    - Payload
      - Moving Optical Sub-Assembly
        - Interferometry Detection System
        - Gravitational Reference System
        - Telescope



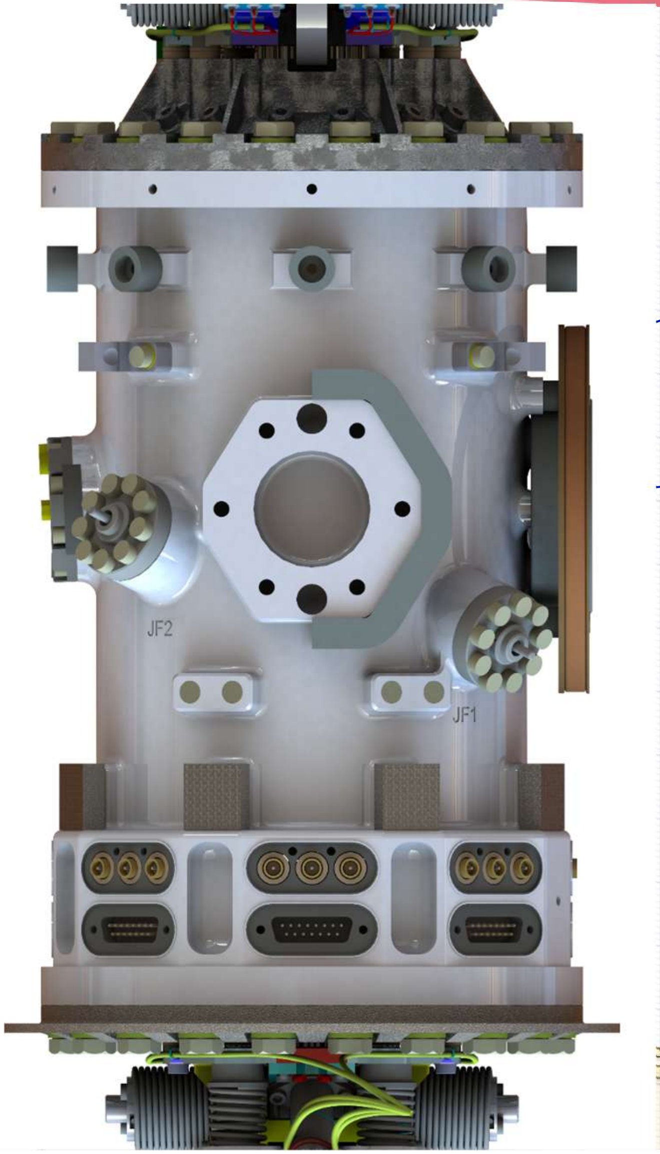
The GRS is the system that impacts the most the acceleration noise performance of the free-falling TM.





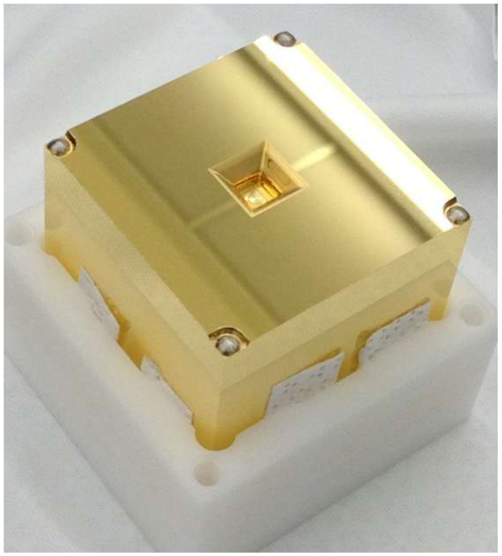
Gravitational Reference System

Design and testing done for LPF, with support from **INFN**.



Electrode Housing (EH)
Mb electrodes coated in Au

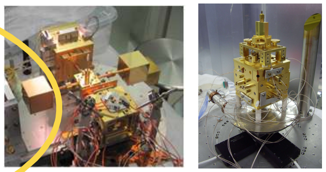
Test Mass (TM)
1.96 kg in Au-Pt



GRS Testing Campaign

It required the involvement of different groups with different expertise to cover all GRS verification needs.
Several customized test facilities have been defined and are under preparation

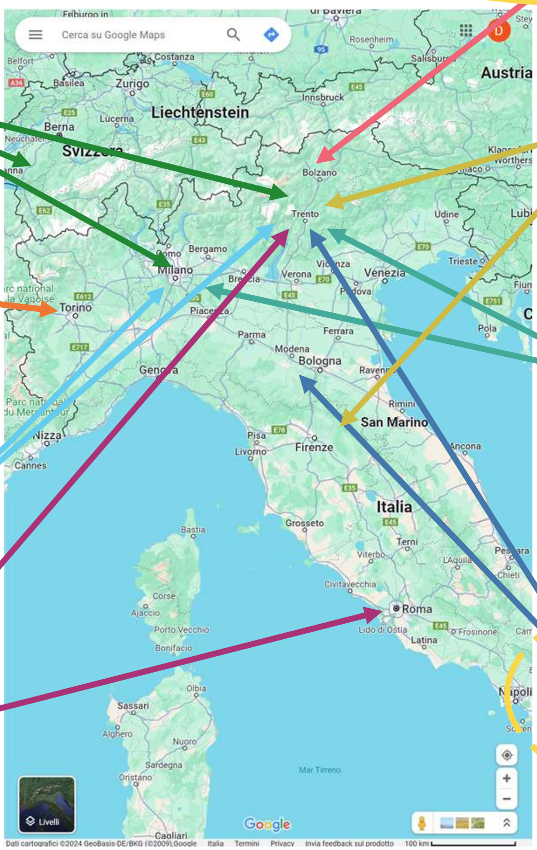
Torsion pendulum tests for force disturbances and CMD performances@ UNITN INFN/TIFPA



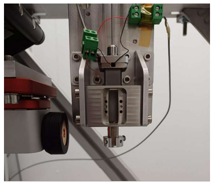
Ougassing measurement facility in collaboration with CERN

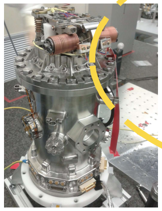
Improved modeling (e.g. *numerical models for charging and discharging of the TMs*) @ UNITN and Urbino University BART:Misura caricamento TM con fascio di protoni

Test mass emulator for LISA system testing and TM metrology @ INRIM (Torino)



Tests of the improved GPRM @ OHB and UNITN

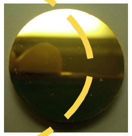




Tests on the EM, QM and flight models @ OHB inlcuding End-2-End test

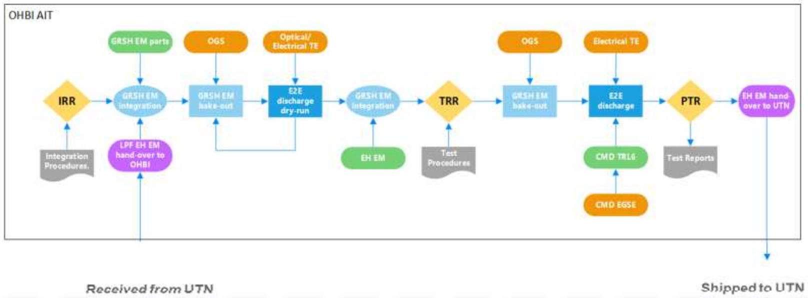
Shape measurement of the UV light at OFT @ INFN Roma 2 and UNITN

EH and TM surface characterization and University of Modena (and FBK)



COURTESY of D. Dal Bosco

EM Testing schedule (UniTN/TIFPA)



EH EM E2E Test @ OHBI

GRS EM Testing @ UniTN/TIFPA

LPF EH FM Replica and CMD TRL6 ULU GSE to OHB — Oct 2025

LISA EH EM Replica and CMD TRL6 GSE to UniTN — June 2026

~12 months

Q2 2027

UniTN/INFN
TP4+ LPF EH FM Replica
TP1+LPF EH prototype
preliminary testing activities and upgrades

UniTN/INFN
Integration on bench of Clock emulator (UniTN)+ FEE breadboard + CMD TRL6
Testing campaign

UniTN/INFN
LISA EH EM Replica integrated in TP4 upgraded +Clock emulator (UniTN)+ FEE BB + CMD TRL6
Testing campaign

UniTN/INFN
LPF prototype integrated in TP1 upgraded +Clock emulator + FEE EM LITE
Testing campaign

Delivery to UniTN of the GRS CMD TRL6 ULU GSE — July 2025

Delivery to UniTN of the GRS FEE BB — Q1 2026

Delivery to UniTN of the GRS FEE EM LITE — Q4 2026

Delivery updated UniTN Testing Plan (end May 2025)

Delivery final UniTN Testing Plan, Integration Procedure, Testing Procedure for UniTN GRS EM level testing TRR @ Q4 2025

UniTN GRS EM level testing TRR for the facility commissioning @ Q1/Q2 2026

EM Testing Plan (UniTN/TIFPA)

INFN UNIVERSITÀ DI TRENTO *LISA GRS*

GRS EM Test Plan
at the University of Trento/INFN TIFPA

LISA-UTN-INST-TP-001
Issue/Rev. 1.0

IN PROGRESS

Consolidate it within the overall GRS testing plan:

list of requirements that will be tested specifying
the limits of testability of the requirements
(e.g., only for some degrees of freedom, only for limited number of contributions to a certain parameter, it allow to place just an upper limit etc...)
the representativeness of the tests,
and the specifications of the "pass and fail" criteria.

Delivery updated UniTN Testing Plan (end May 2025)

Delivery final UniTN Testing Plan, Integration Procedure, Testing Procedure for UniTN GRS EM level testing TRR @ Q4 2025

UniTN GRS EM level testing Delta-TRR for the facility commissioning @ Q1/Q2 2026

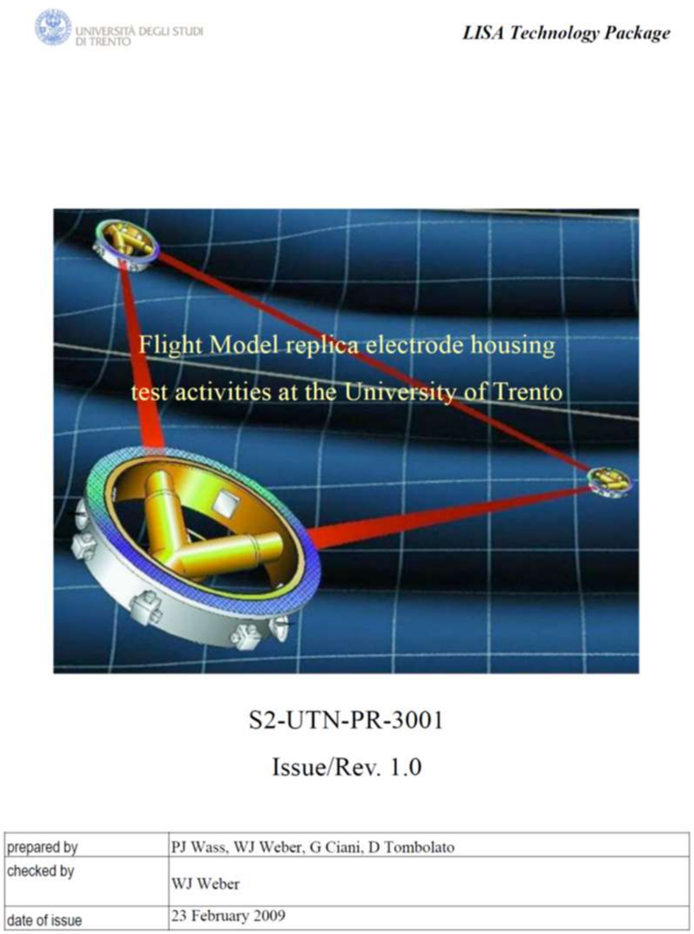
ALREADY INCLUDED:

Preliminary description of the individual test campaigns

List of requirements whose compliance is demonstrated or supported by these tests

Description of facilities and of test configuration

LPF experience/heritage



UNIVERSITÀ DEGLI STUDI DI TRENTO

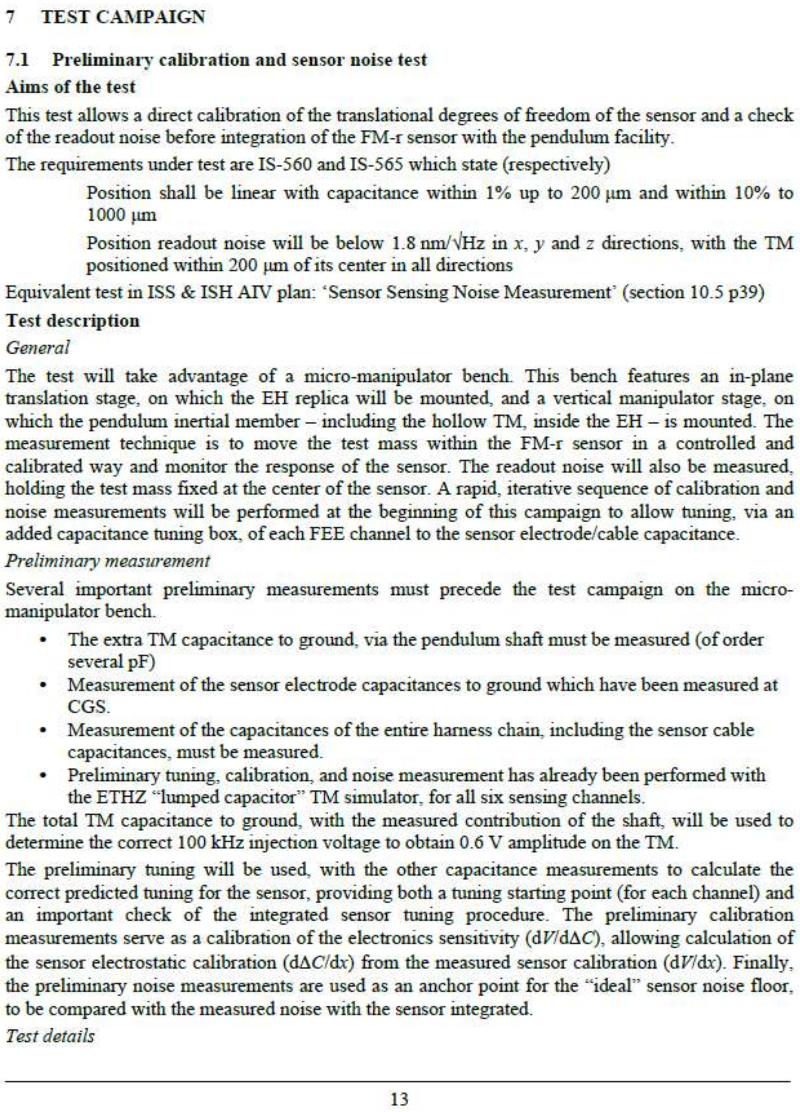
LISA Technology Package

Flight Model replica electrode housing test activities at the University of Trento

S2-UTN-PR-3001

Issue/Rev. 1.0

prepared by	PJ Wass, WJ Weber, G Ciani, D Tombolato
checked by	WJ Weber
date of issue	23 February 2009



7 TEST CAMPAIGN

7.1 Preliminary calibration and sensor noise test

Aims of the test

This test allows a direct calibration of the translational degrees of freedom of the sensor and a check of the readout noise before integration of the FM-r sensor with the pendulum facility.

The requirements under test are IS-560 and IS-565 which state (respectively)

> Position shall be linear with capacitance within 1% up to 200 μm and within 10% to 1000 μm
>
> Position readout noise will be below 1.8 nm/√Hz in x, y and z directions, with the TM positioned within 200 μm of its center in all directions

Equivalent test in ISS & ISH AIV plan: 'Sensor Sensing Noise Measurement' (section 10.5 p39)

Test description

General

The test will take advantage of a micro-manipulator bench. This bench features an in-plane translation stage, on which the EH replica will be mounted, and a vertical manipulator stage, on which the pendulum inertial member – including the hollow TM, inside the EH – is mounted. The measurement technique is to move the test mass within the FM-r sensor in a controlled and calibrated way and monitor the response of the sensor. The readout noise will also be measured, holding the test mass fixed at the center of the sensor. A rapid, iterative sequence of calibration and noise measurements will be performed at the beginning of this campaign to allow tuning, via an added capacitance tuning box, of each FEE channel to the sensor electrode/cable capacitance.

Preliminary measurement

Several important preliminary measurements must precede the test campaign on the micro-manipulator bench.

- The extra TM capacitance to ground, via the pendulum shaft must be measured (of order several pF)
- Measurement of the sensor electrode capacitances to ground which have been measured at CGS.
- Measurement of the capacitances of the entire harness chain, including the sensor cable capacitances, must be measured.
- Preliminary tuning, calibration, and noise measurement has already been performed with the ETHZ "lumped capacitor" TM simulator, for all six sensing channels.

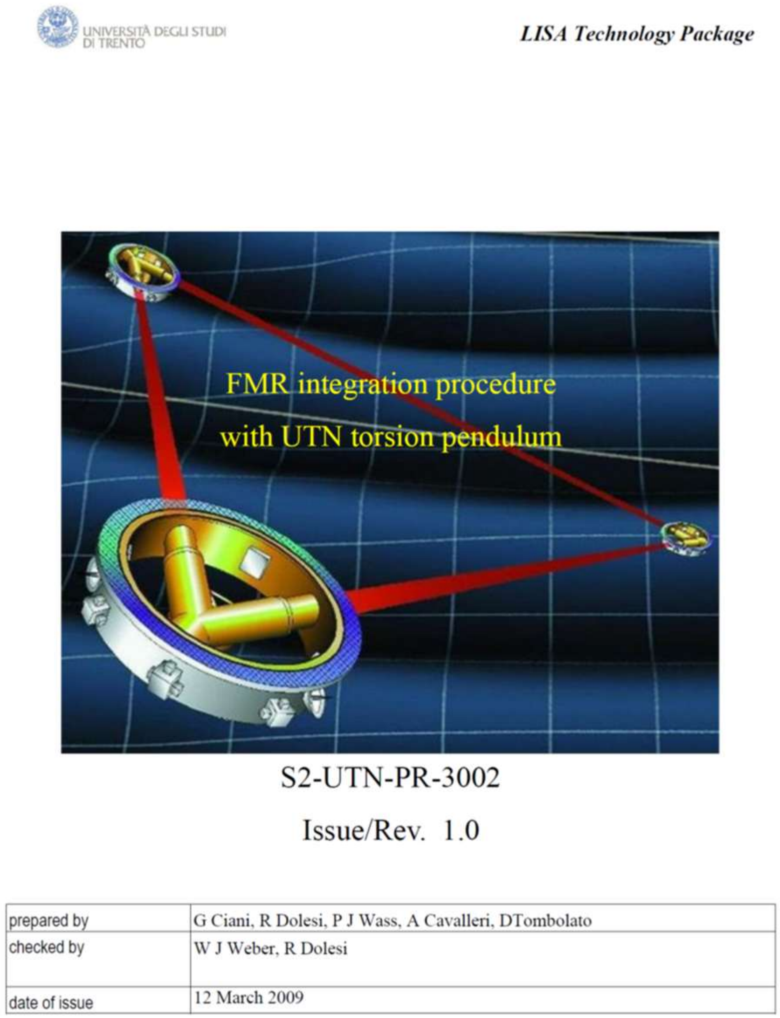
The total TM capacitance to ground, with the measured contribution of the shaft, will be used to determine the correct 100 kHz injection voltage to obtain 0.6 V amplitude on the TM.

The preliminary tuning will be used, with the other capacitance measurements to calculate the correct predicted tuning for the sensor, providing both a tuning starting point (for each channel) and an important check of the integrated sensor tuning procedure. The preliminary calibration measurements serve as a calibration of the electronics sensitivity ($dV/d\Delta C$), allowing calculation of the sensor electrostatic calibration ($d\Delta C/dx$) from the measured sensor calibration (dV/dx). Finally, the preliminary noise measurements are used as an anchor point for the "ideal" sensor noise floor, to be compared with the measured noise with the sensor integrated.

Test details

13

LPF experience/heritage



UNIVERSITÀ DEGLI STUDI DI TRENTO

LISA Technology Package

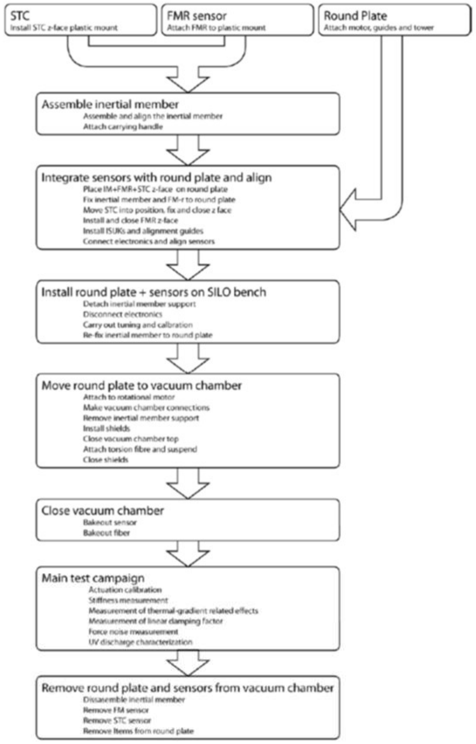
FMR integration procedure

with UTN torsion pendulum

S2-UTN-PR-3002

Issue/Rev. 1.0

prepared by	G Ciani, R Dolesi, P J Wass, A Cavalleri, DTombolato
checked by	W J Weber, R Dolesi
date of issue	12 March 2009



STC
Install STC z-face plastic mount

FMR sensor
Attach FMR to plastic mount

Round Plate
Attach motor, guides and tower

Assemble inertial member
- Assemble and align the inertial member
- Attach carrying handle

Integrate sensors with round plate and align
- Place IM+FMR+STC z-face on round plate
- Fix inertial member and FM-r to round plate
- Move STC into position, fix and close z face
- Install and close FMR z-face
- Install ISUKs and alignment guides
- Connect electronics and align sensors

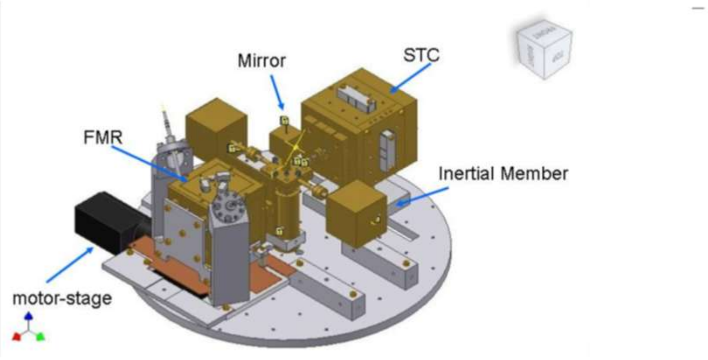
Install round plate + sensors on SILO bench
- Detach inertial member support
- Disconnect electronics
- Carry out tuning and calbration
- Re-fix inertial member to round plate

Move round plate to vacuum chamber
- Attach to rotational motor
- Make vacuum chamber connections
- Remove inertial member support
- Install shields
- Close vacuum chamber top
- Attach torsion fibre and suspend
- Close shields

Close vacuum chamber
- Bakeout sensor
- Bakeout fiber

Main test campaign
- Actuation calibration
- Stiffness measurement
- Measurement of thermal-gradient related effects
- Measurement of linear damping factor
- Force noise measurement
- UV dischage characterization

Remove round plate and sensors from vacuum chamber
- Dissasemble inertial member
- Remove FM sensor
- Remove STC sensor
- Remove Items from round plate

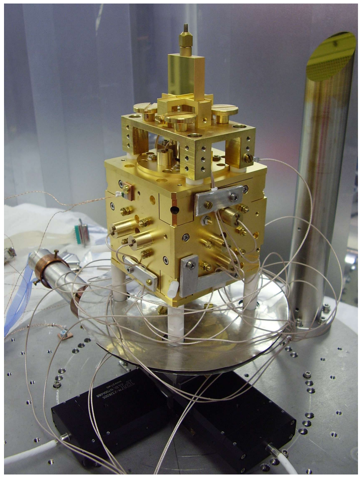


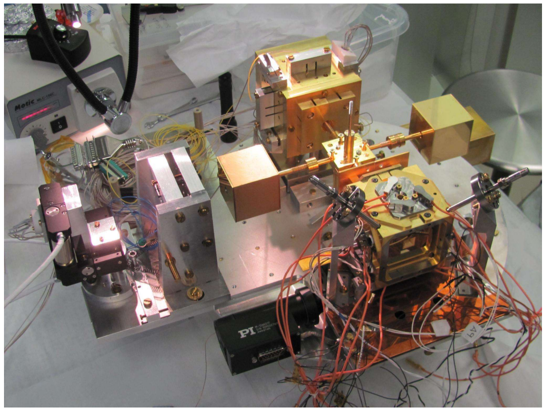
Torsion pendulum testing for LISA

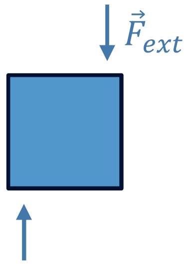
Torsion pendulums are unique tools to test the LISA Gravitational Reference System (GRS)

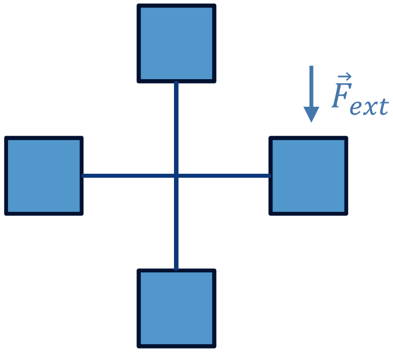
1. *1TM torsion pendulum*: more sensitive, but to torques only
2. *4TM torsion pendulum*: directly sensitive to forces as TM is mounted off-center (~10 cm arm)

Hollow test masses → sensitive to surface forces rather than bulk forces





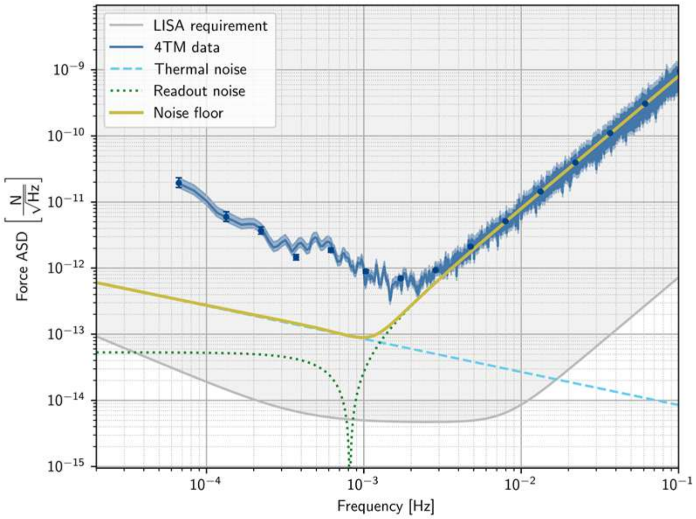




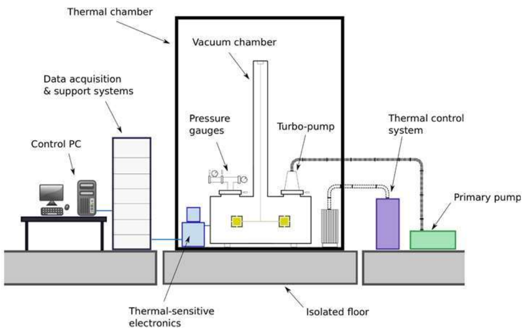
Torsion pendulum testing for LISA

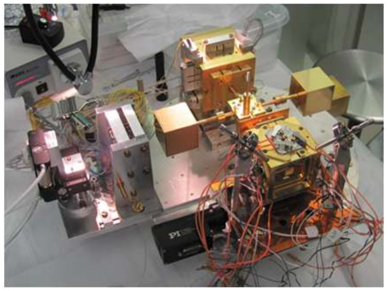
4TM torsion pendulum @ UniTN/TIFPA

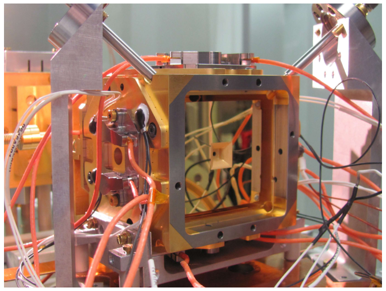
The 4TM torsion pendulum aims at testing several functionalities and the force noise on the TM in the most representative way possible.



Can test many known effects to LISA requirement levels (at 2 mHz we can resolve a force 10 fN in 1 hour)





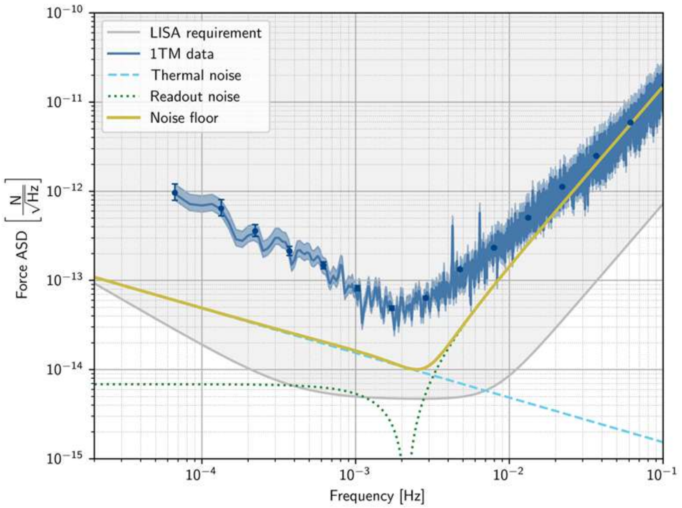


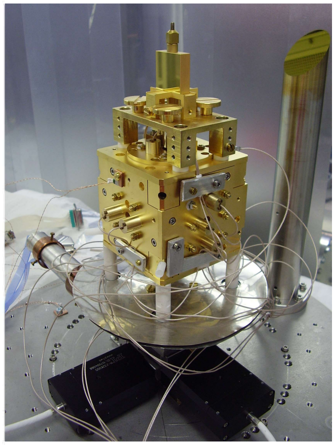
Torsion pendulum testing for LISA

1TM torsion pendulum @ UniTN/TIFPA

The LISA testing campaign will include the 1TM pendulum, which is the most sensitive facility, but only to disturbances that produce torque!

- 10 times more sensitive to noises coming from electrodes (FEE *actuation noise and stray fields*)
- Dedicated force tests with smaller TM-EH gaps (enhance electrostatic disturbances ~ $1/d^2$)
- Possible test on gas bursts (*glitches*)





Noise is a factor 6 above LISA requirement at ~mHz

Preliminary tests on bench

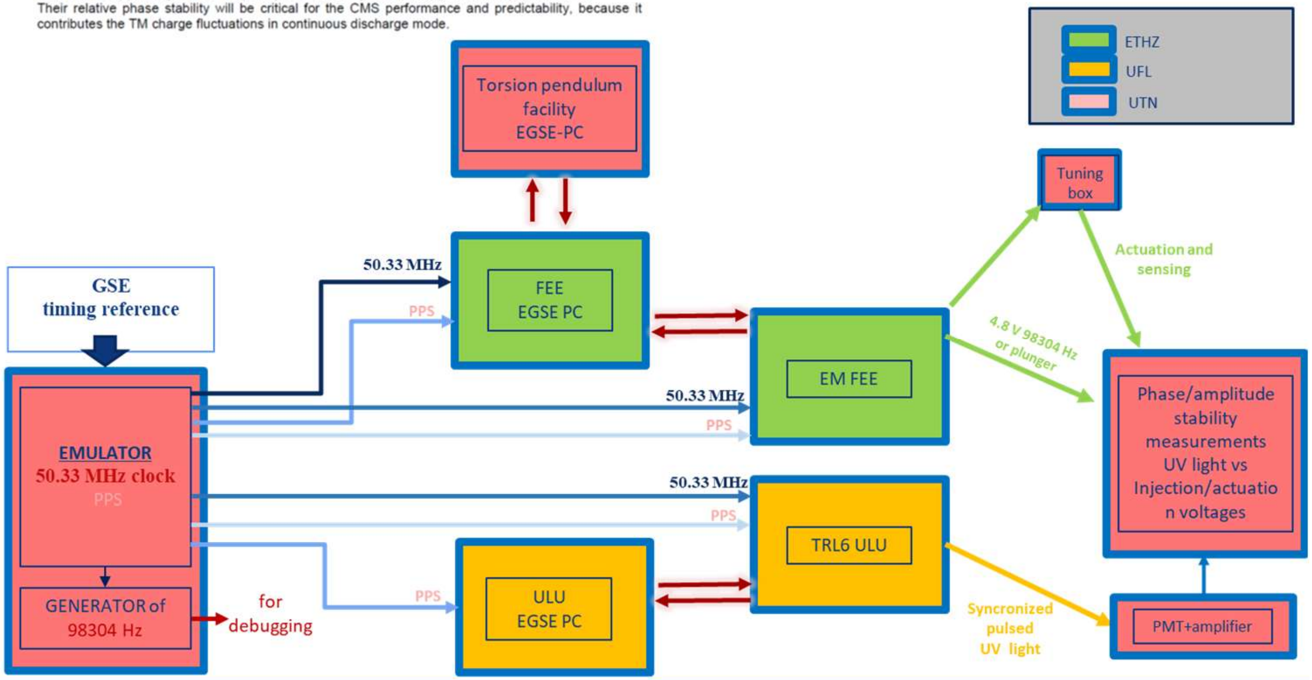
To obtain an overall phase noise between UV light pulses and FEE 98304 Hz injection voltage of 10 mrad/$Hz^{1/2}$, the following allocation to the FEE and to the CMD (for the phase stability measured with respect to an ideal 98304 Hz signal derived from the 10 MHz SC master oscillator) has been proposed (according to LISA-UTN-INST-TN-014) :

GRS-FEE-6 Injection phase stability
The injection phase stability should be below 7 mrad/$Hz^{1/2}$ in the LISA frequency band.
GRS-CMD-14 Pulsed light phase noise
The phase noise for 98304 kHz UV pulses should be less than 7 mrad/$Hz^{1/2}$ in the LISA freq. Band

While these two requirement will be verified at FEE and CMD unit level, @ UniTN/INFN we test at GRS level the overall phase noise between UV light pulses and FEE 98304 Hz injection voltage of 10 mrad/$Hz^{1/2}$, by implementing the testing configuration described in 6.2.2

6.2.2 Testing configuration for relative phase stability between FEE and CMD

Both the FEE injection frequency and the CMD UV illumination pulse frequency will be derived from the 50.33 MHz supplied by the SC frequency distribution system (FDS) provided at platform level. Their relative phase stability will be critical for the CMS performance and predictability, because it contributes the TM charge fluctuations in continuous discharge mode.



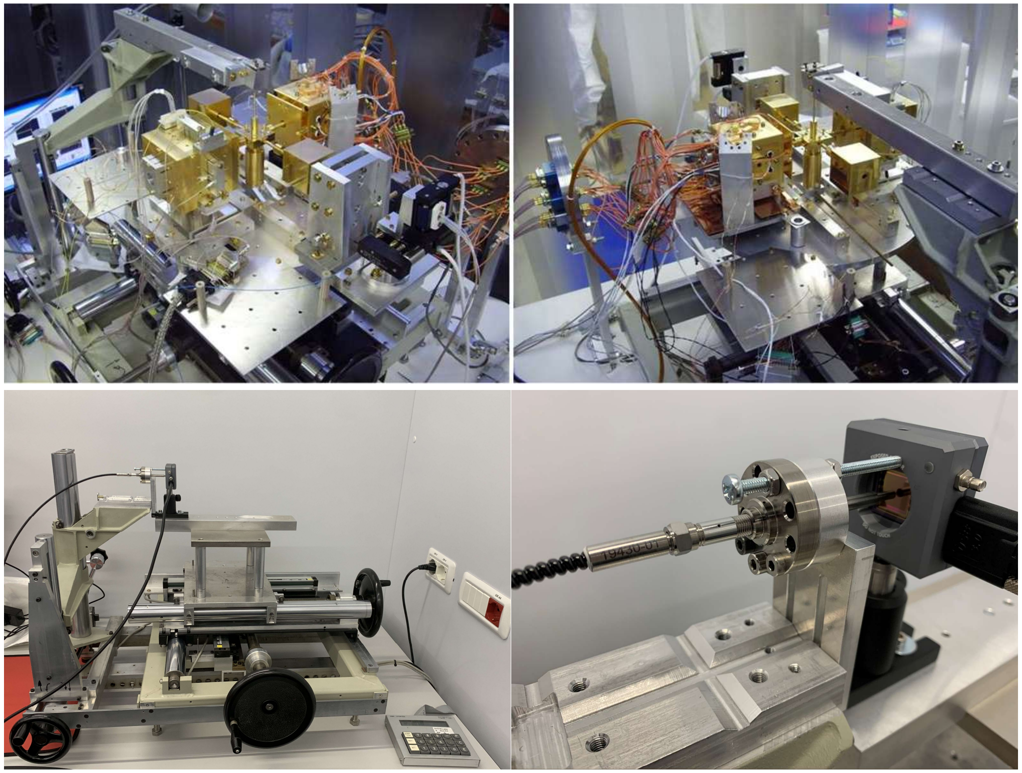
The phase stability measurements are obtained connecting the fast PMT output to a lock-in amplifier Stanford Research Systems SR-830 with reference the injection/actuation bias coming from the GRS FEE SAU Elegant Breadboard/ GRS FEE SAU EM Lite.

Preliminary tests on bench

Micro manipulator bench

Micro-meter accuracy in x, y, and z translation.

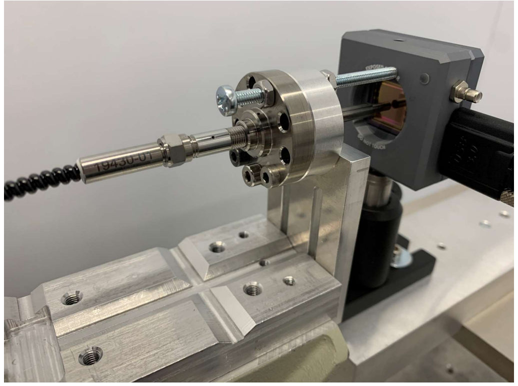
- Calibration measurements of the front-end electronics for capacitive sensing
- Preliminary UV light cone profiling from new fiber bundles + Optical Feed-Through



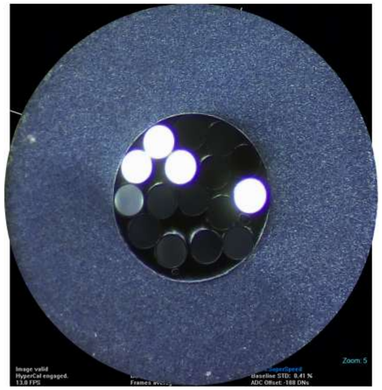
Preliminary tests on bench

UV light beam shape measurements preliminary investigation performed

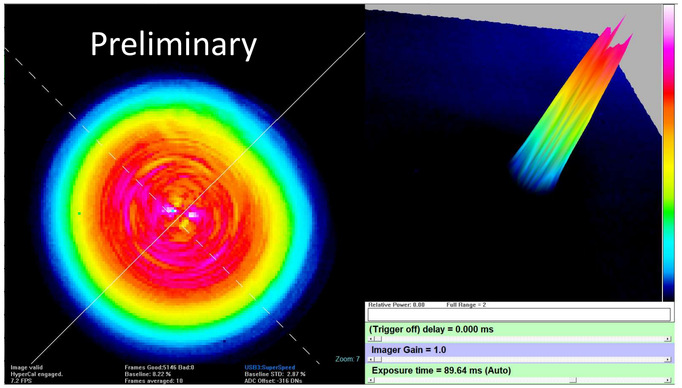
The light distribution from the OFT affects the CMS performance



Experimental setup



UV light at fiber bundle



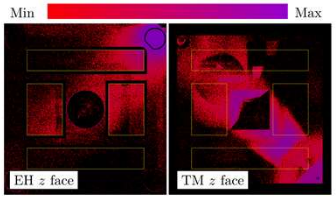
(Trigger off) delay = 0.000 ms

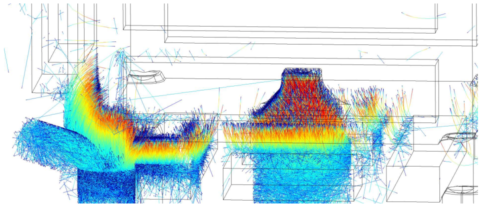
Imager Gain = 1.0

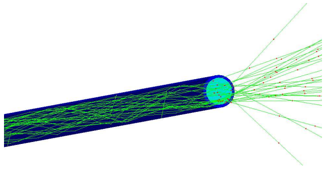
Exposure time = 89.64 ms (Auto)

UV light at OFT

Simulation and numerical studies by Francesco Dimiccoli, Valerio Ferroni and Davide Vignotto







Interface with CMS: impact of the UV light cone aperture

Input for setting up the FOH/OFT interface
requirement for the LISA TM charge
management system

In GEANT4, a model capable of reproducing the light coming out of the FOH (from direct measurements of its intensity) and propagating it inside the OFT to simulate the cone shape

Using the CMS simulator, we trace the UV light inside the GRS with a GEANT4 tool and feed the photon absorption information to a FEM model in COMSOL to trace UV photoelectrons as a function of the TM potential

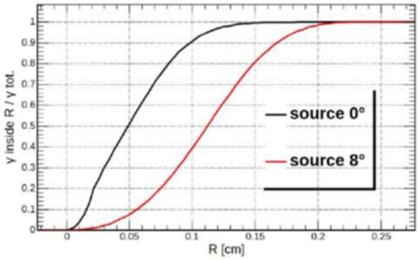
V.Ferroni, F.Dimiccoli, D.Dal Bosco , T. Klaser, A.Cavalleri,

Tilting single source fiber:

8 deg tilted
spacer unde
LED

Impact of the UV light cone aperture

Simulation:



Measurements

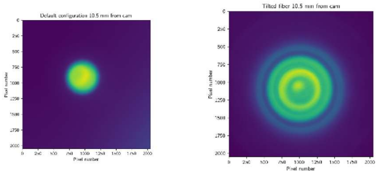


Figura 26: A sinistra l'immagine di una sezione del fascio UV con il led non inclinato rispetto alla fibra ottica, a destra il fascio allargato dall'inclinazione.

Simulation

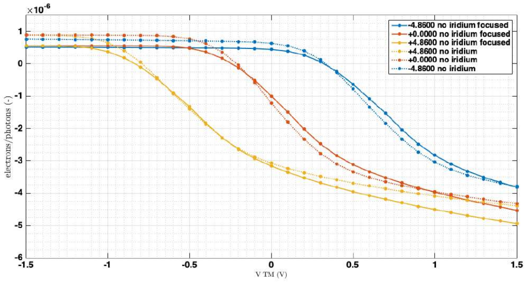


Figure 13: Simulated Apparent yield curves with current torsion pendulum facility geometrical configuration for nominal "wide" (9deg) and "focused" (4.5deg) light cone with illumination in phase, out of phase and with zero injection. About 50mV decrease of equilibrium potential is observed illuminating with "focused" light cone. Quantum yield at 10^{-5} and 4eV work function assumed uniform for all the involved surfaces.

Meausrements with TP4

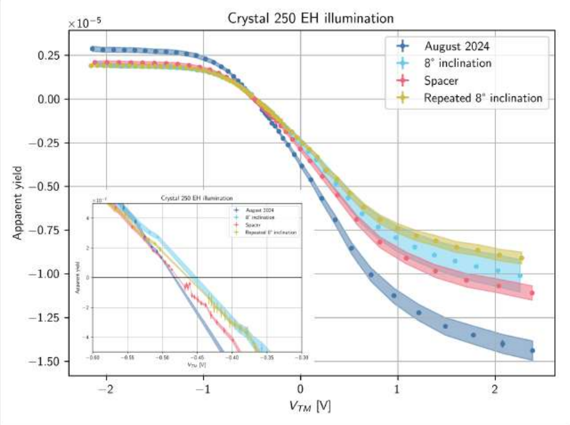


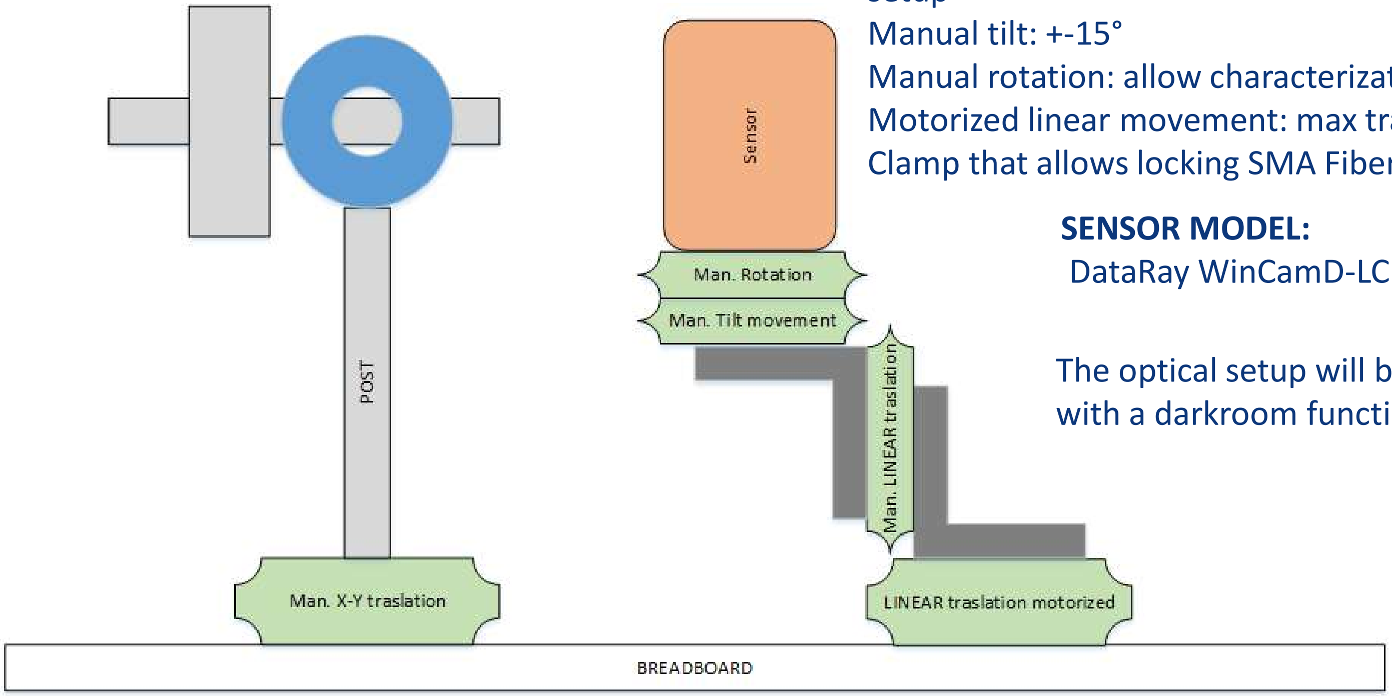
Figure 12: Apparent yield curves in no bias configuration (no applied voltages) as measured in torsion pendulum facility for "nominal" ±4deg (August 2024 and "spacer") and "defocused" ±8deg (8deg inclination, two repetitions) apertures.

UV light beam shape measurement setup

Optical Test setup – Block Diagram and description

An optical test setup is currently being integrated for the characterization and verification of the radiation diagram of:

- LEDs,
- Optical Feedthrough



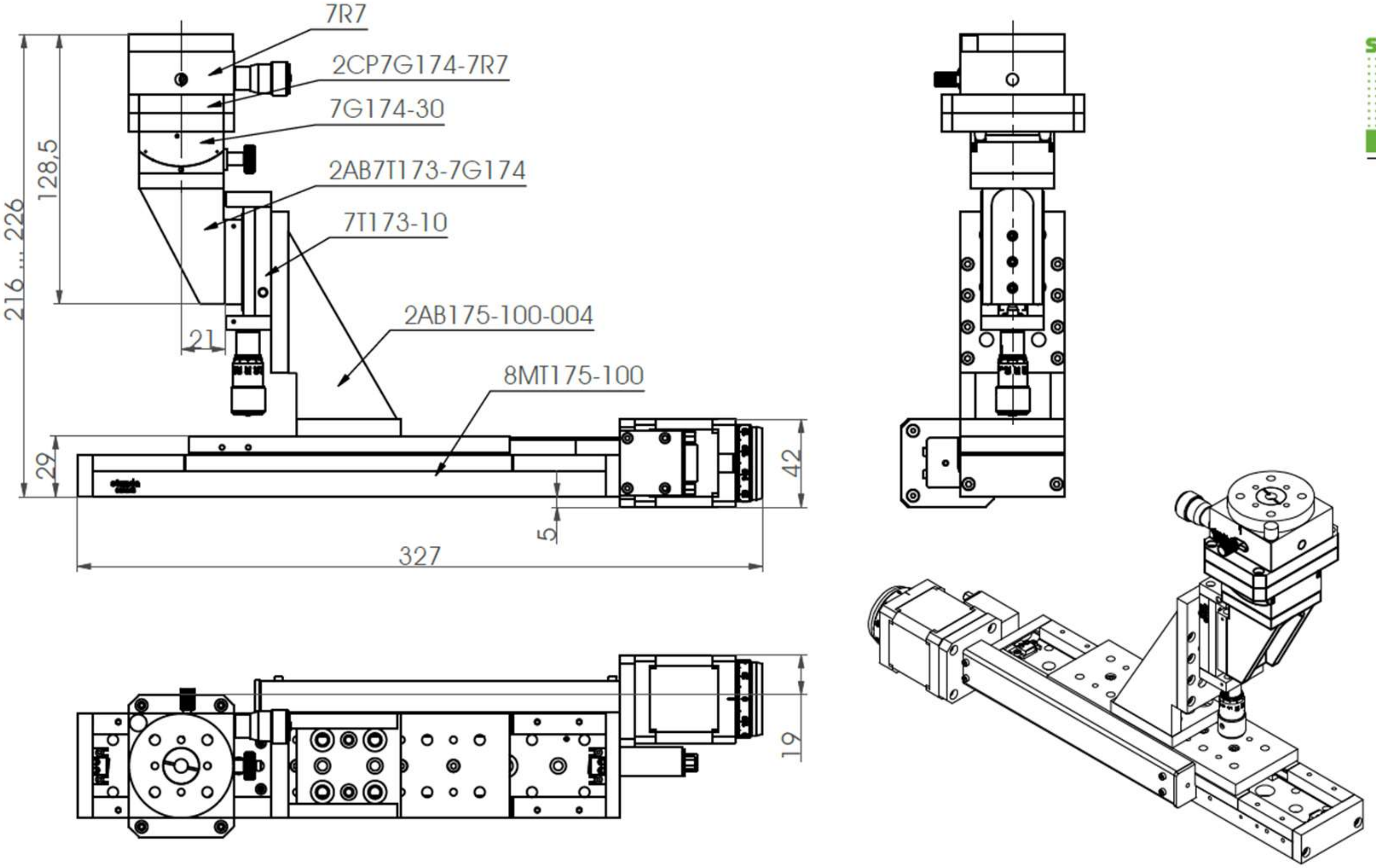
Main Characteristics:
Manual X,Y,Z movement: for centering the DUT in the measurement setup
Manual tilt: +-15°
Manual rotation: allow characterization on range +-45° (precision 1°)
Motorized linear movement: max travel 100mm (sensitivity 1µm)
Clamp that allows locking SMA Fiber and custom optical feedthrough

SENSOR MODEL:
DataRay WinCamD-LCM (part number: S-WCD-LCM)

The optical setup will be housed inside a box with a darkroom function.

UV light beam shape measurement setup

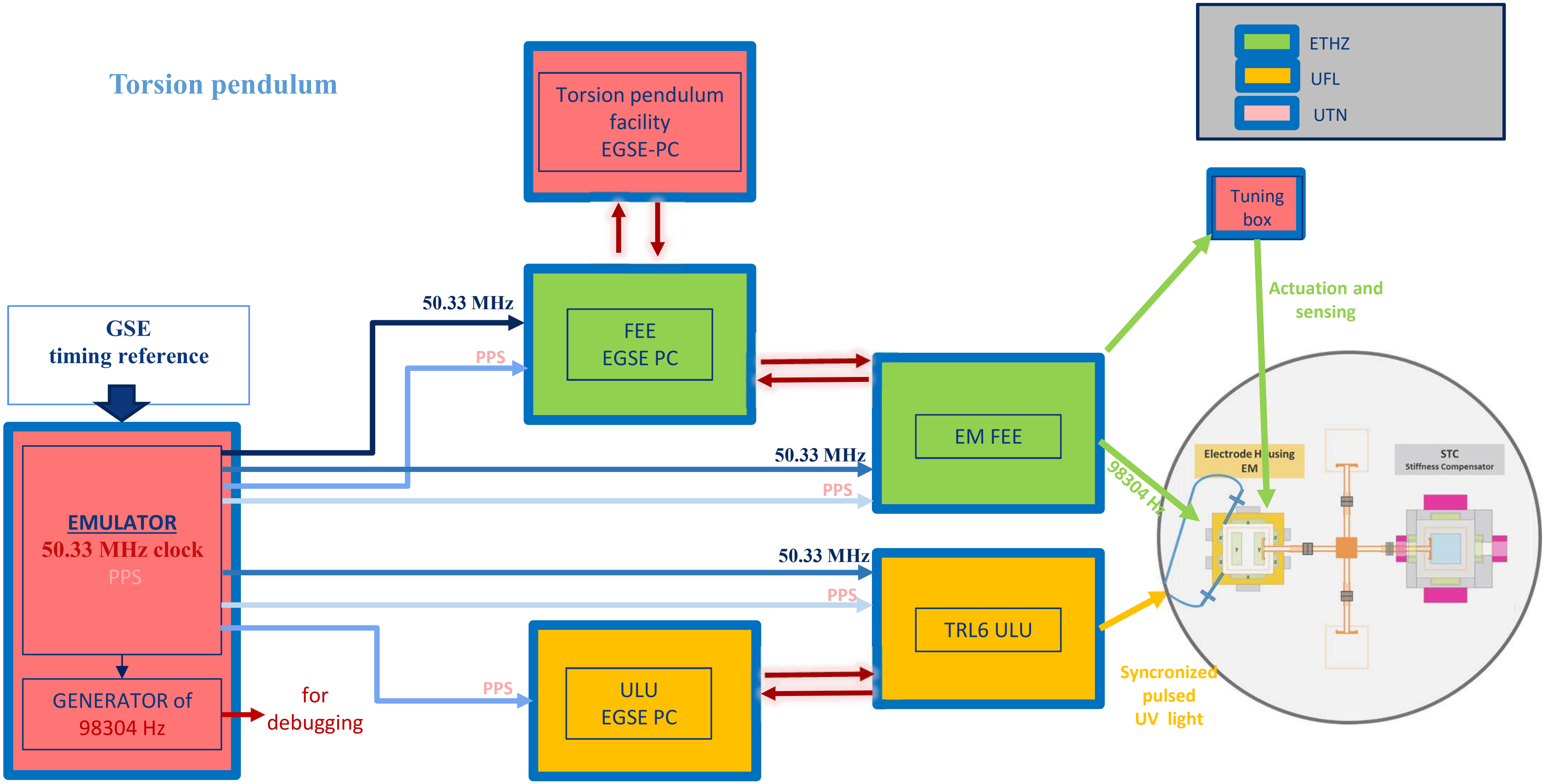
Optical Test setup – Mechanical sketch



standa

Torsion pendulum testing for LISA

Torsion pendulum



🟩 ETHZ
🟨 UFL
🟥 UTN

Torsion pendulum facility EGSE-PC

Tuning box

GSE timing reference

FEE EGSE PC

EM FEE

EMULATOR
50.33 MHz clock
PPS

GENERATOR of 98304 Hz

for debugging

ULU EGSE PC

TRL6 ULU

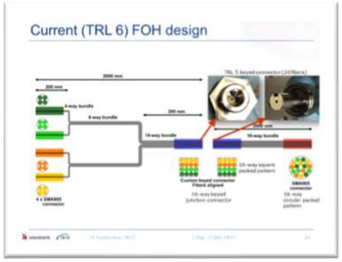
50.33 MHz
PPS

Actuation and sensing

98304 Hz

Syncronized pulsed UV light

Torsion pendulum testing for LISA


Current (TRL 6) FOH design

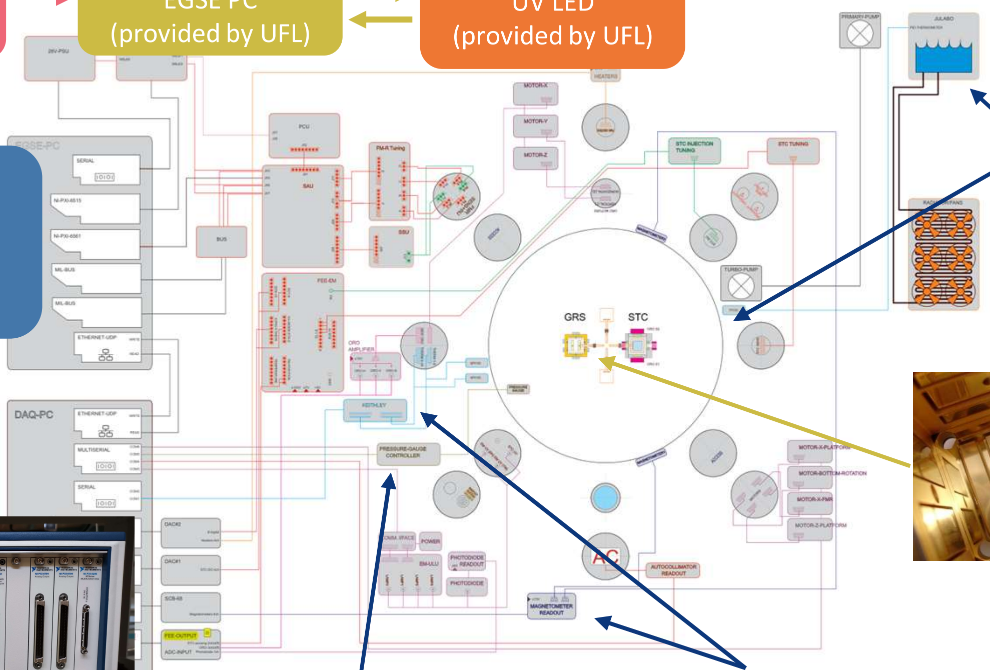
New UV FOH (fiber bundles)

Spacecraft timing emulator

ULU
EGSE PC
(provided by UFL)

TRL6 ULU
UV LED
(provided by UFL)

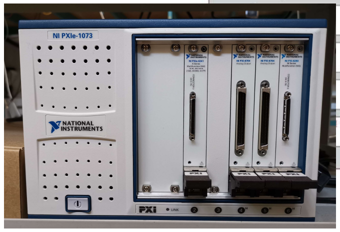
LISA FEE
EGSE PC & FEE Elegant breadboard/EM1 lite
(provided by ETHZ)



Vacuum chamber mounted in thermally controlled room

Engineering model of LISA EH

Torsion pendulum facility EGSE-PC (provided by UNITN)



Pressure gauge and RGA

Magnetometers and thermometers

Funded by INFN

Testing with the 4TM torsion pendulum

List of planned tests:

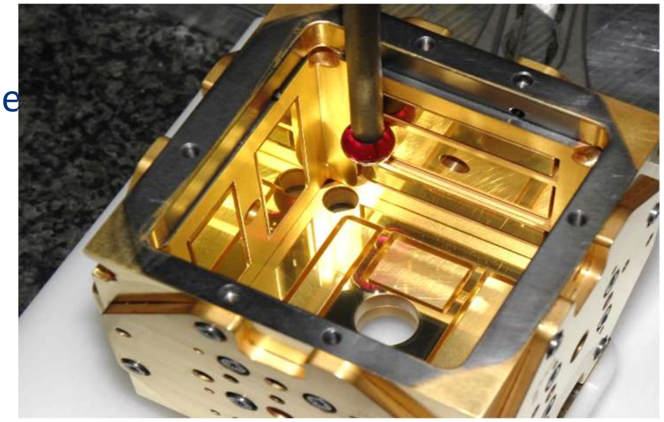
- Capacitive sensor performance (sensing and actuation)
- Stiffness from injection, actuation, DC voltages, and TM charge
- Stray voltages (Δ_x)
- Thermal effects (dg/dT, dg/d Δ T)
- Full-discharge test including continuous discharge
- Surface properties (yield for photoelectric emission, patch potentials, …)
- Overall force noise

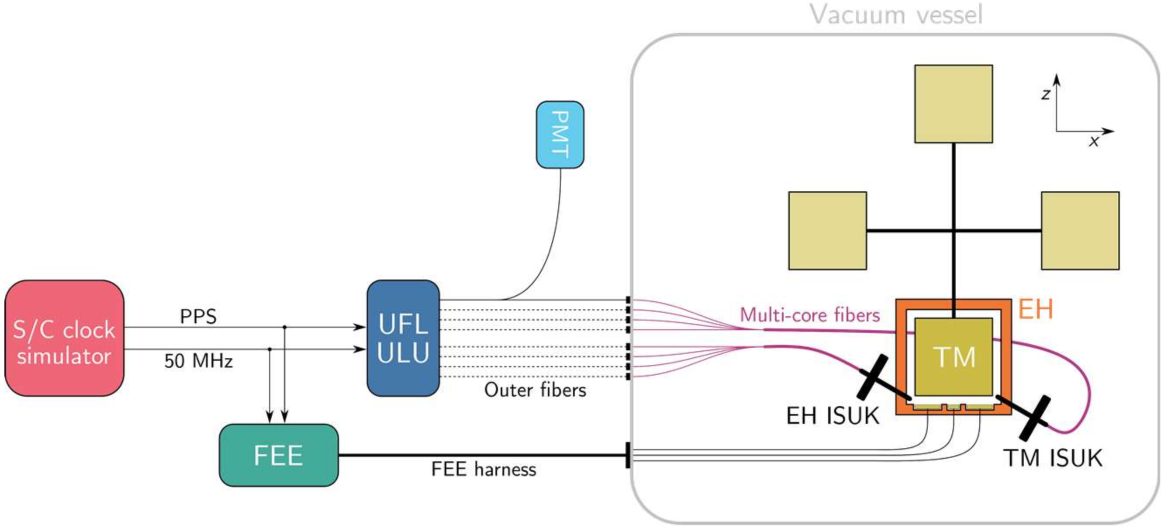
For details see:

GRS EM Test Plan
at the University of Trento/INFN TIFPA

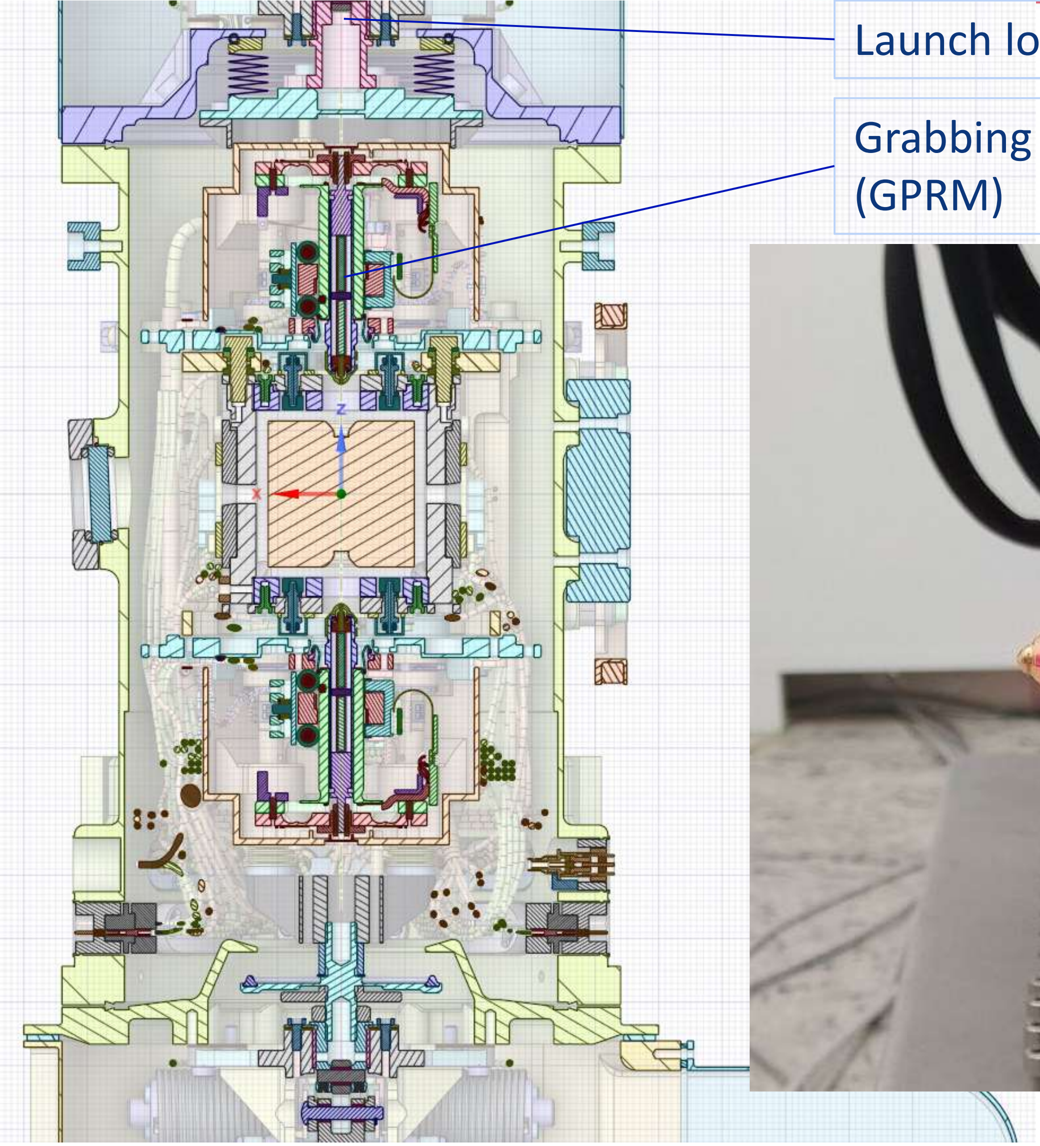
LISA-UTN-INST-TP-001
Issue/Rev. 1.0

LISA EM EH Funded by INFN+ASI



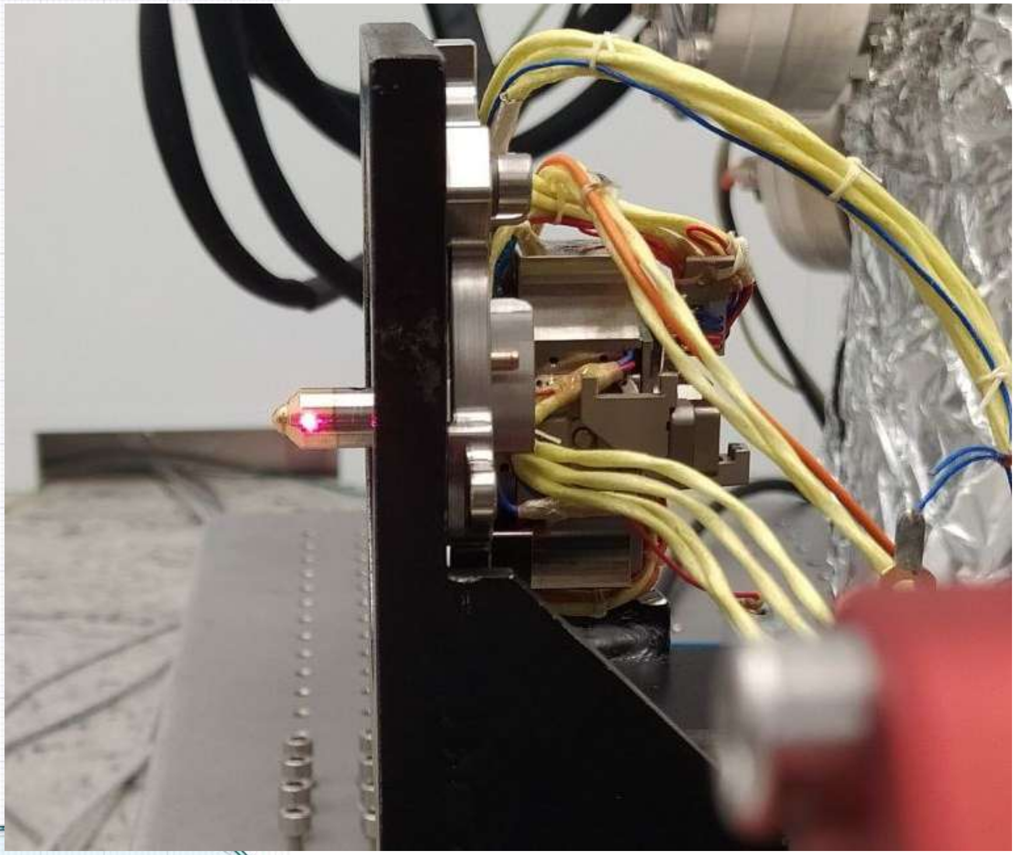


GRS Unique Mechanisms



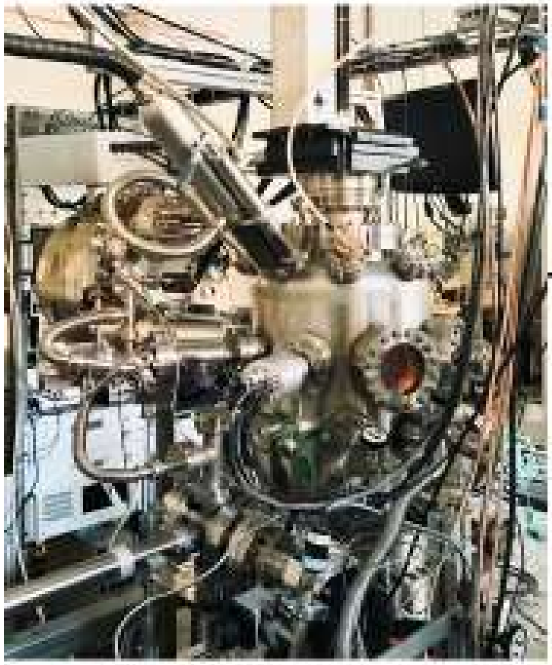
Launch lock (CVM)

Grabbing positioning and release mechanism (GPRM)



EH and TM surface samples characterization

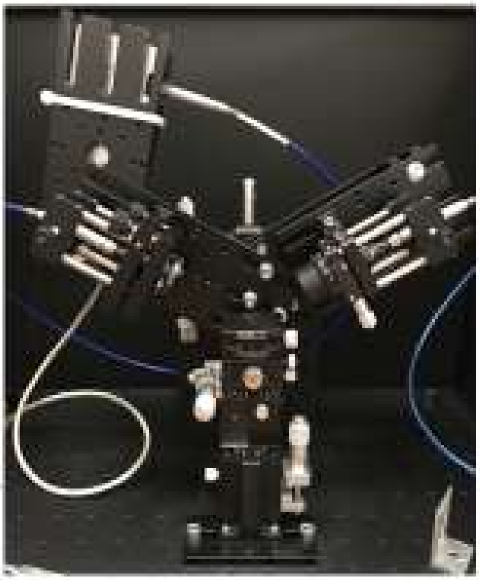
Lab fisica materiali e superfici (LFMS @ DIEF)



- X-ray photoelectron spectroscopy
- Angle resolved Ultraviolet photoelectron spectroscopy + linear polarization
- Auger electron spectroscopy
- Electron Energy Loss spectroscopy

- Sample treatments in UHV
- Evaporation cells

- Vis-UV absorption & reflectivity
- Luminescence



Luca Pasquali

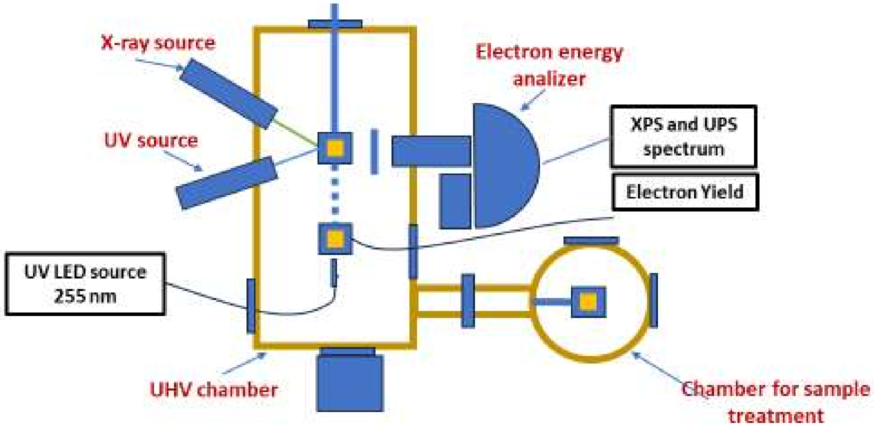
EH and TM surface samples characterization

Example of measurements on representative samples

At the Laboratory of Physics of Materials and Surfaces of the Enzo Ferrari Engineering Department of the University of Modena and Reggio Emilia.

Type of measurements:

- Characterization by **UV photoemission spectroscopy** (source with 21.2 eV photons): valence band and work function – photoelectric threshold.
- **X-ray photoemission spectroscopy** (eventually angle resolved) (source with Mg K_{alfa} and/or Al K_{alfa} photons): elementary chemical characterization.
- **photoelectric yield** in ultra-high vacuum with a representative LED source connected to the analysis chamber by optical fibers
- **Sputtering** cycles with argon ions and in-situ annealing (where necessary).
- **Bake-out tests** to simulate real conditions in a dedicated chamber, connected to the UHV analysis chamber – without the need to break the vacuum for the previous and subsequent characterization.
- Repetitions of the characterizations **after aging** – both in vacuum and in air.
- Measurements of **reflectivity of the surfaces at various angles** at the wavelength of interest (in air)



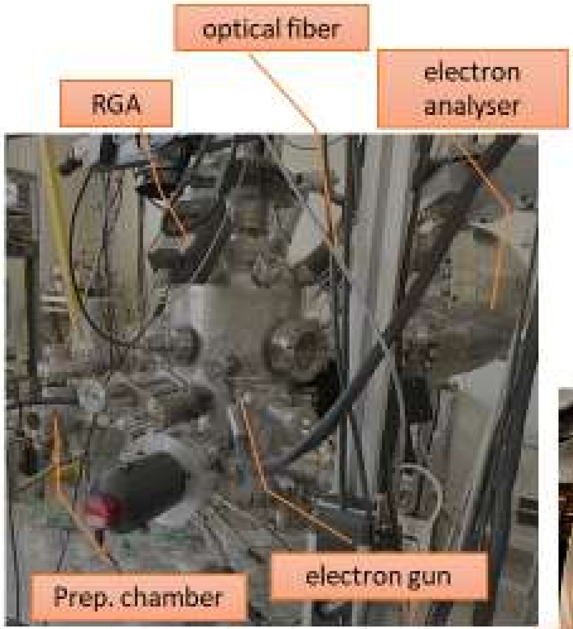
COURTESY of T. Klaser

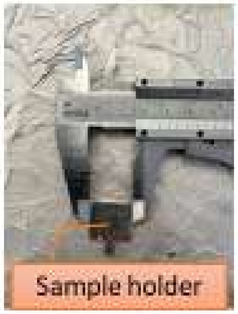
UNIMORE

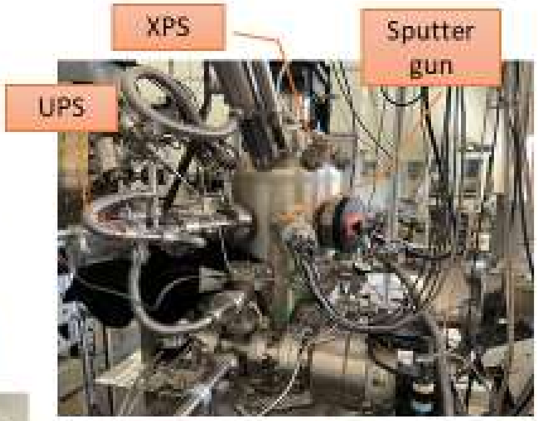
EH and TM surface samples characterization

SCHEDULE:

- Commissioning+ preparation for TRR (within Sept 2025)
- EH surfaces samples measurement campaign Q4 2025
- TM surfaces samples measurement campaign Q1 2026
- Witness sample EM→FM EH and TM surfaces (TBC)

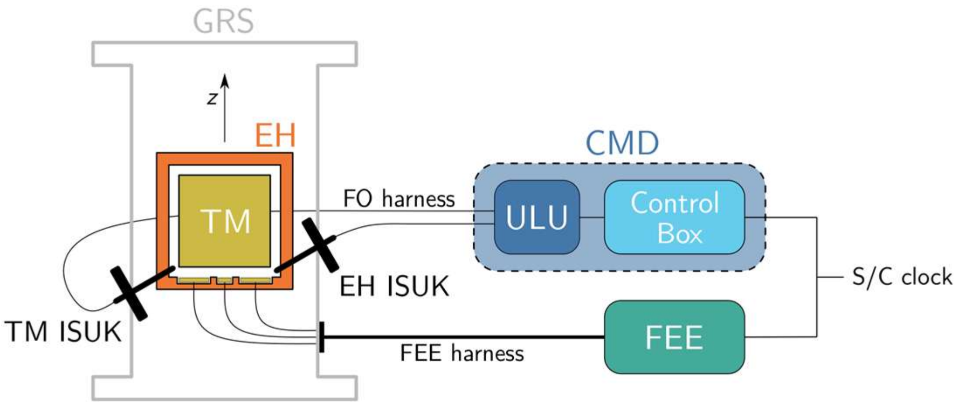


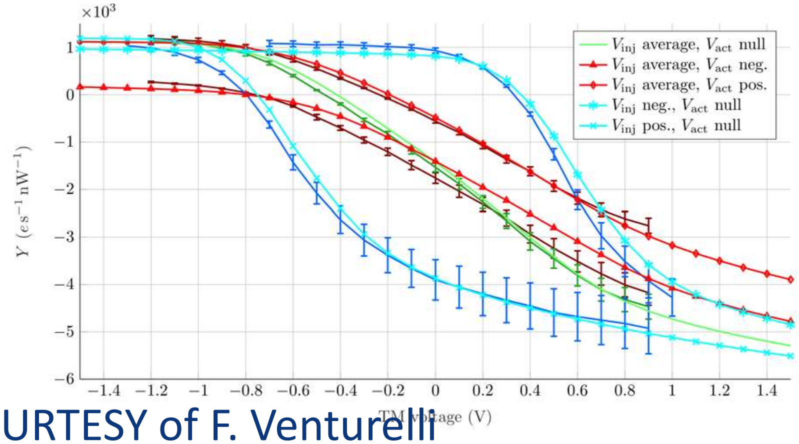


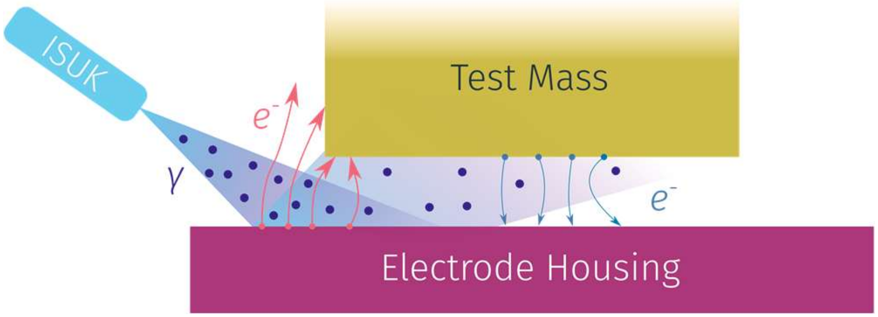


UniTN support to EM End2End Testing @ OHB I

To support OHB testing activity at EM/QM/FM level regarding the discharge mechanism, with a direct measurement (“end-2-end”) of the photo-current produced by UV illumination of the TM and EH surfaces, a new facility has been built in Trento.



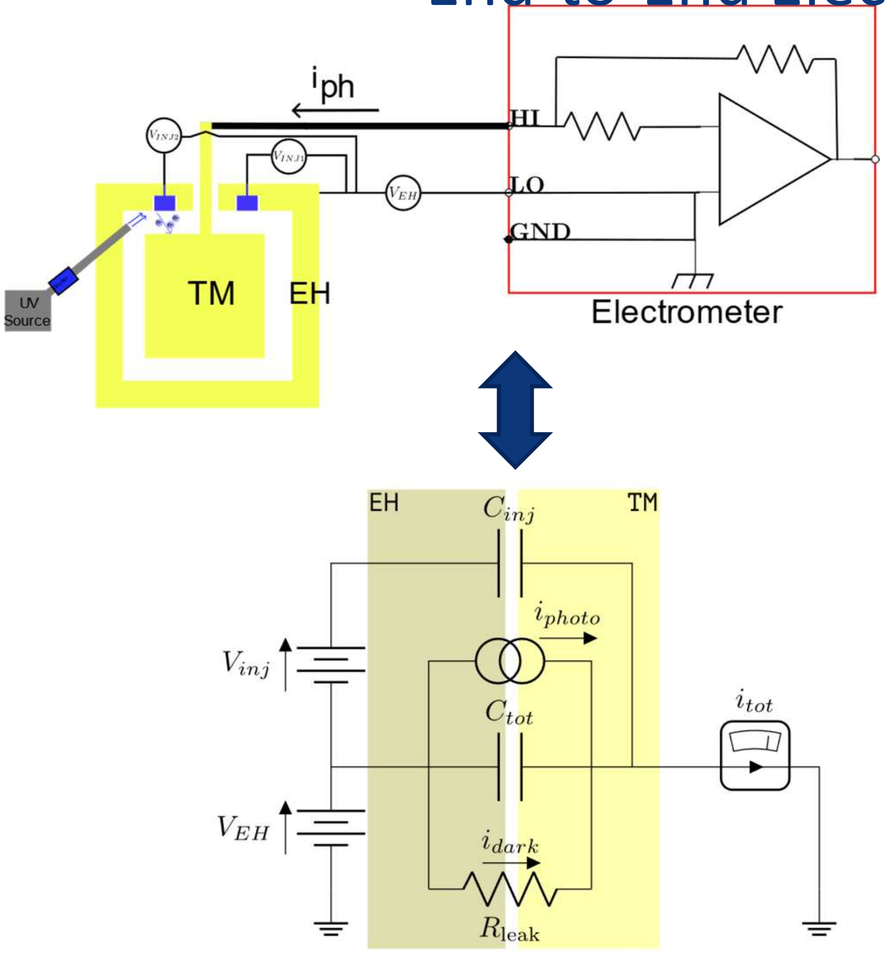




COURTESY of F. Venturelli

UniTN support to EM End2End Testing @ OHB I

End-to-End Electrical configuration



True in End-to-End, pendulums and in flight

$$\Delta V = V_{TM} - V_{EH} = \alpha V_{inj} + V_{TM0}$$

$\alpha = C_{inj}/C_{tot} = 0.12$

Since V_{TM} is always at GND

$$\begin{cases} \widehat{V_{EH}} = -V_{TM} = -(V_{TM0} + \alpha V_{inj}) \\ \widehat{V_{inj}} = V_{inj} \end{cases}$$

The measured current is proportional to the apparent yield

$$Y(-\widehat{V_{EH}}) = Y(V_{TM0} + \alpha \widehat{V_{inj}}; \widehat{V_{inj}})$$

UniTN support to EM End2End Testing @ OHB I

Pulsed Illumination Emulation

$$\begin{cases} \widehat{V_{EH}} = -V_{TM} = -(V_{TM0} + \alpha V_{inj}) \\ \widehat{V_{inj}} = V_{inj} \end{cases}$$

- Measured discharge curves with fixed V_{inj} exploring V_{EH}
- Fixing V_{inj} is a equivalent to choosing a phase ϕ(or delay) of the pulsed light in respect to the injection poten $V_{inj} = 4.9\sin(2\pi f_{inj}t)$
- Total measurement time : 17 #V_{inj} x 40 #V_{EH} x 100 s x 6 #cycles = 113 h 20 min ~ 4 days

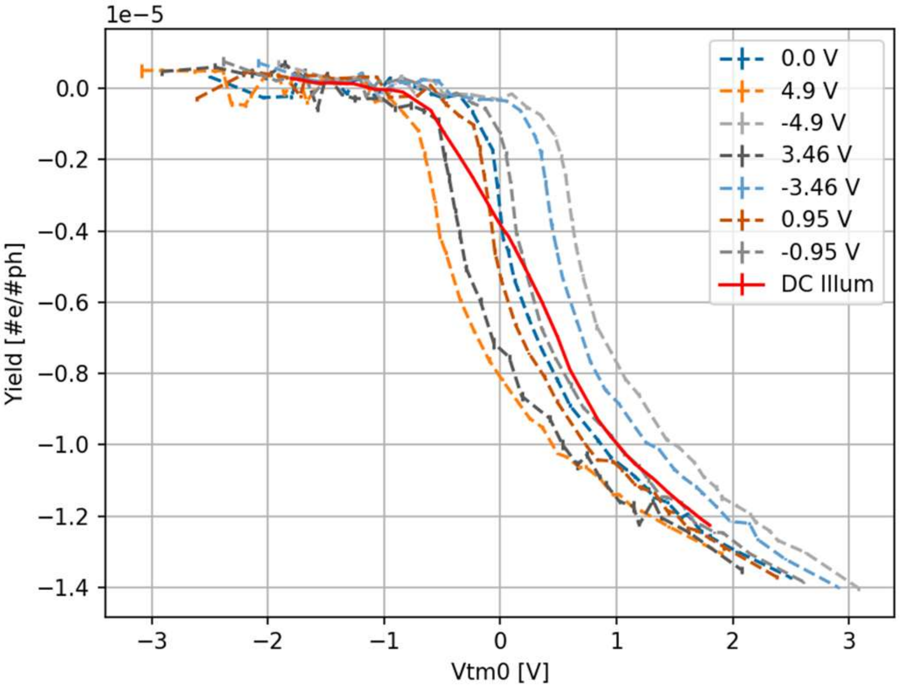
DC Illumination Emulation

$$Y(V_{TM0}) = \left\langle Y(V_{TM0} + \alpha\widehat{V_{inj}}(\phi); \widehat{V_{inj}}(\phi))\right\rangle |_{\phi\in[\pi/2,3/2\pi]}$$

- Averaging over V_{inj}(or ϕ) for each V_{TM0} is the same as the net effect of $V_{inj} = 4.9\sin(2\pi f_{inj}t)$ od
- To be consistent the average must be performed over a uniform grid of ϕ in [π/2;3π/2], half period is enough

Accordance to model:

- ✓ In pulsed illumination, V_{TM} = -V_{EH} dominates the dynamics, the curves are almost the same
- ✓ In pulsed illumination, as a function of V_{TM0} the curves are shifted accordingly to -αV_{inj}
- ✓ In DC illumination, the curve slope is less sharp



UniTN support to EM End2End Testing @ OHB I

Testing and verification strategies

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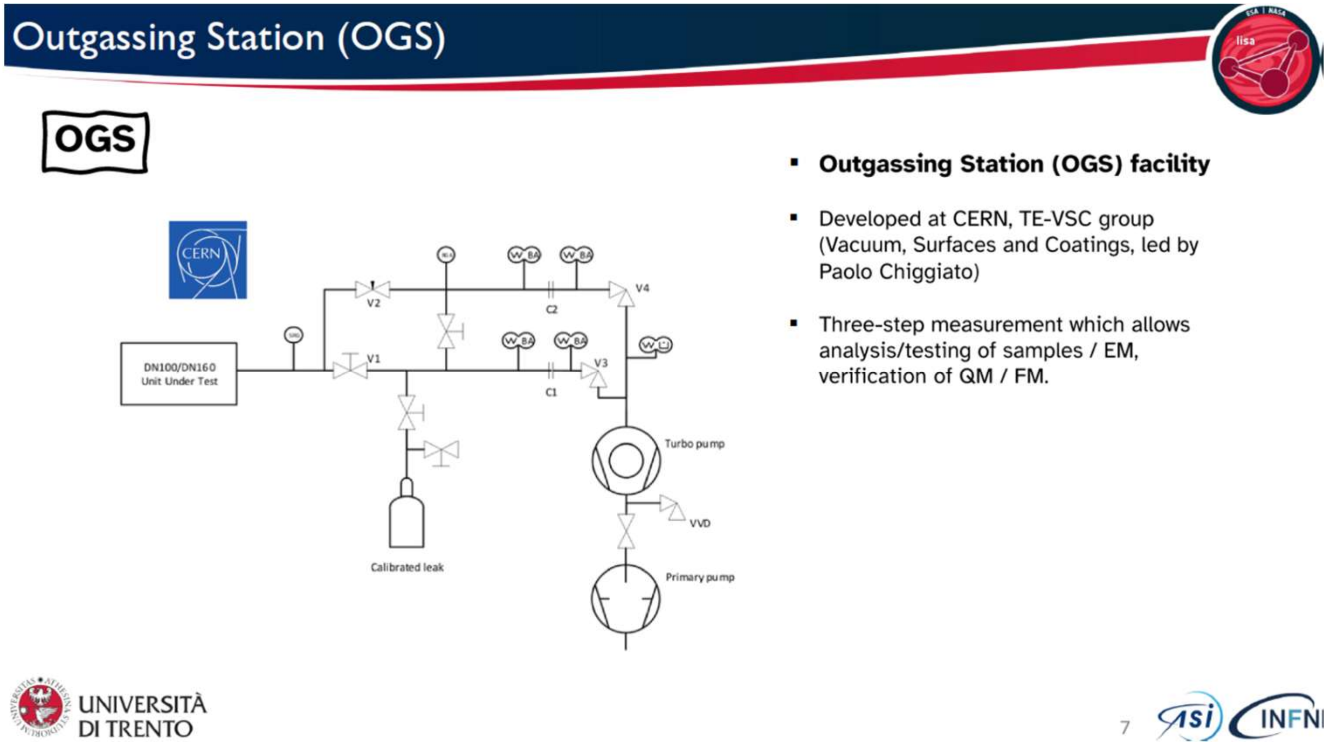


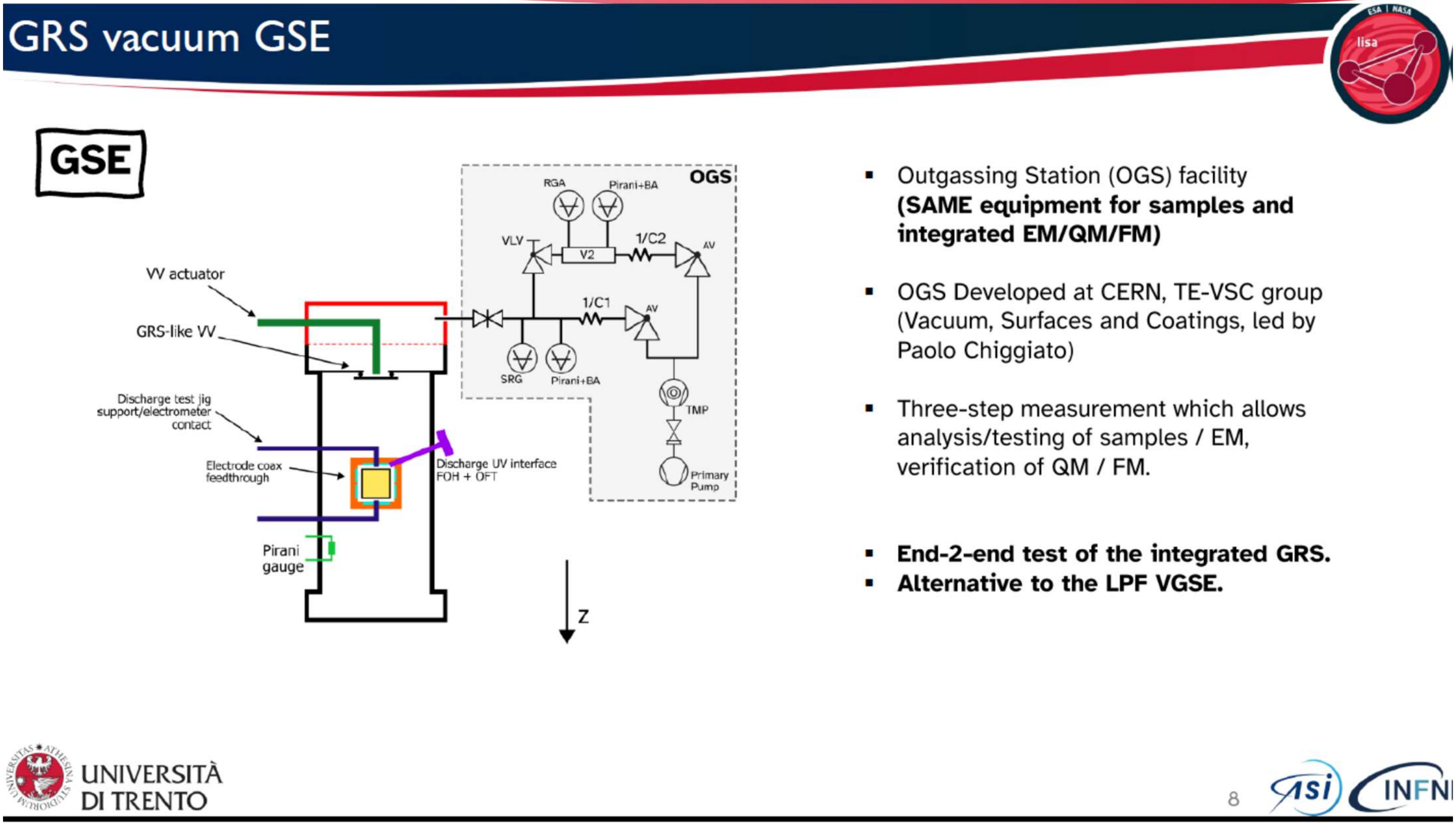
Outgassing Station (OGS)

OGS

- **Outgassing Station (OGS) facility**
- Developed at CERN, TE-VSC group (Vacuum, Surfaces and Coatings, led by Paolo Chiggiato)
- Three-step measurement which allows analysis/testing of samples / EM, verification of QM / FM.

COURTESY of Lorenzo Sala

UniTN support to EM End2End Testing @ OHB I



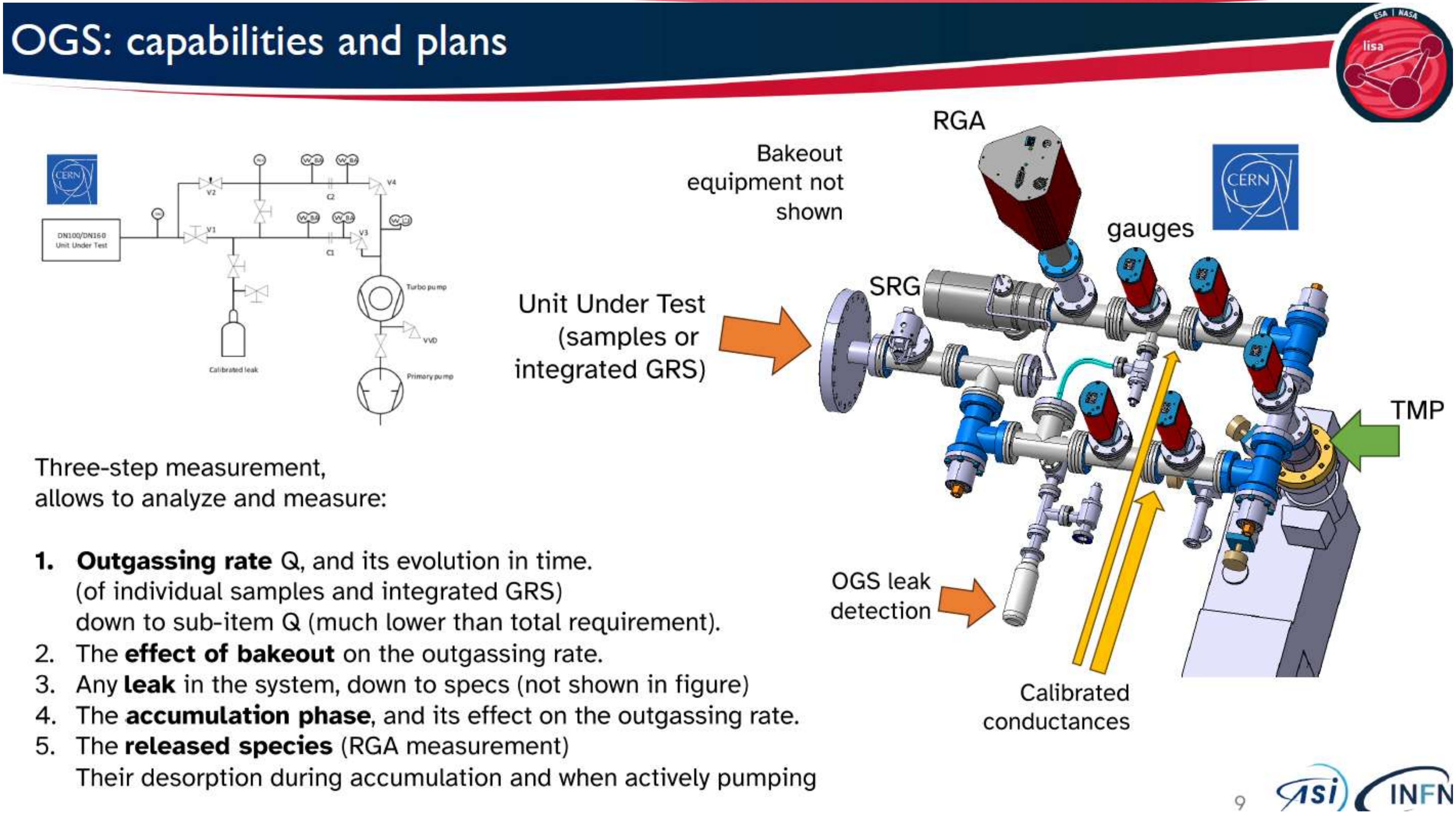
GRS vacuum GSE

- Outgassing Station (OGS) facility **(SAME equipment for samples and integrated EM/QM/FM)**
- OGS Developed at CERN, TE-VSC group (Vacuum, Surfaces and Coatings, led by Paolo Chiggiato)
- Three-step measurement which allows analysis/testing of samples / EM, verification of QM / FM.

- **End-2-end test of the integrated GRS.**
- **Alternative to the LPF VGSE.**

8

UniTN support to EM End2End Testing @ OHB I

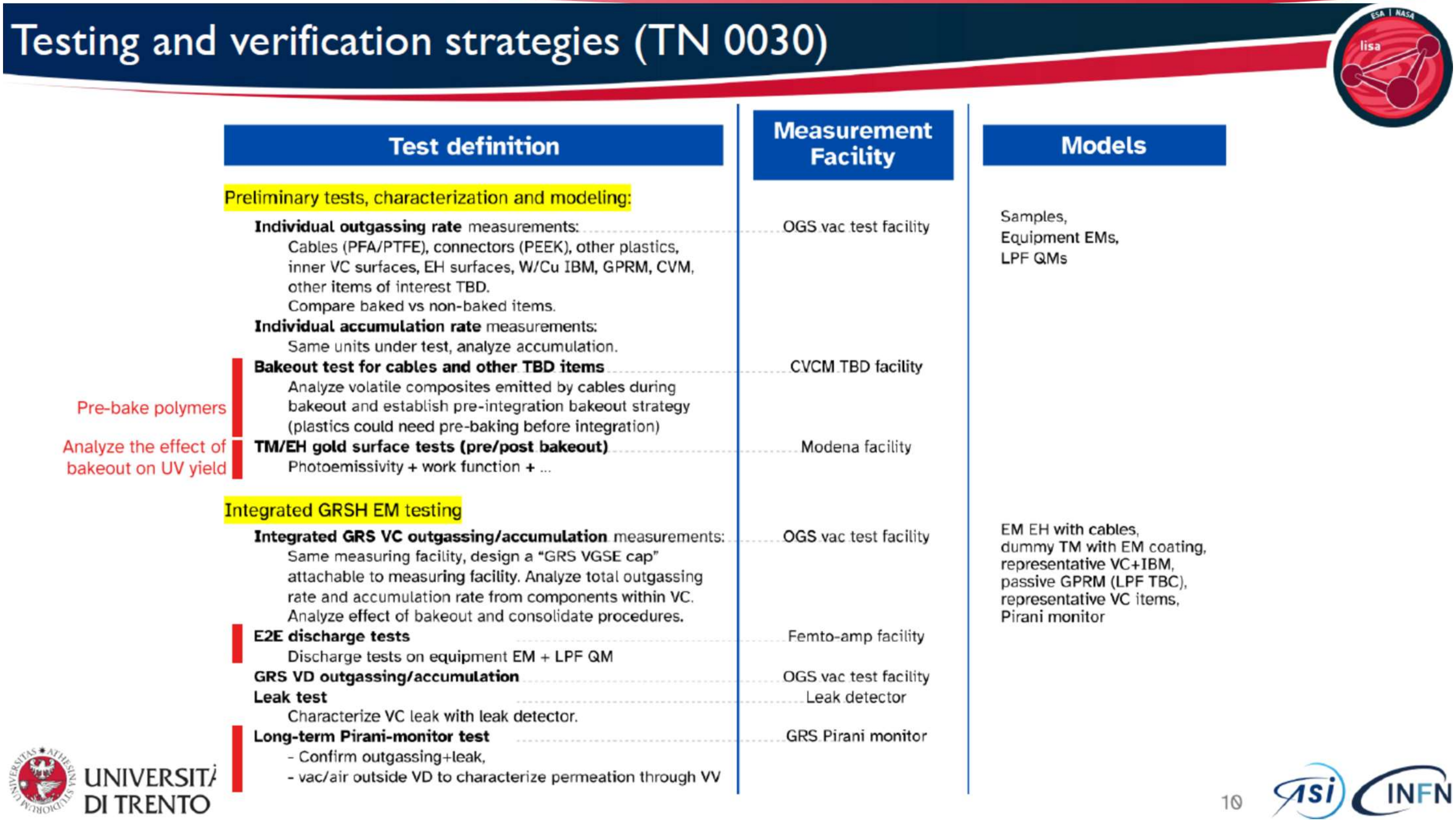


OGS: capabilities and plans

Three-step measurement,
allows to analyze and measure:

1. **Outgassing rate** Q, and its evolution in time. (of individual samples and integrated GRS) down to sub-item Q (much lower than total requirement).
2. The **effect of bakeout** on the outgassing rate.
3. Any **leak** in the system, down to specs (not shown in figure)
4. The **accumulation phase**, and its effect on the outgassing rate.
5. The **released species** (RGA measurement) Their desorption during accumulation and when actively pumping

UniTN support to EM End2End Testing @ OHB I

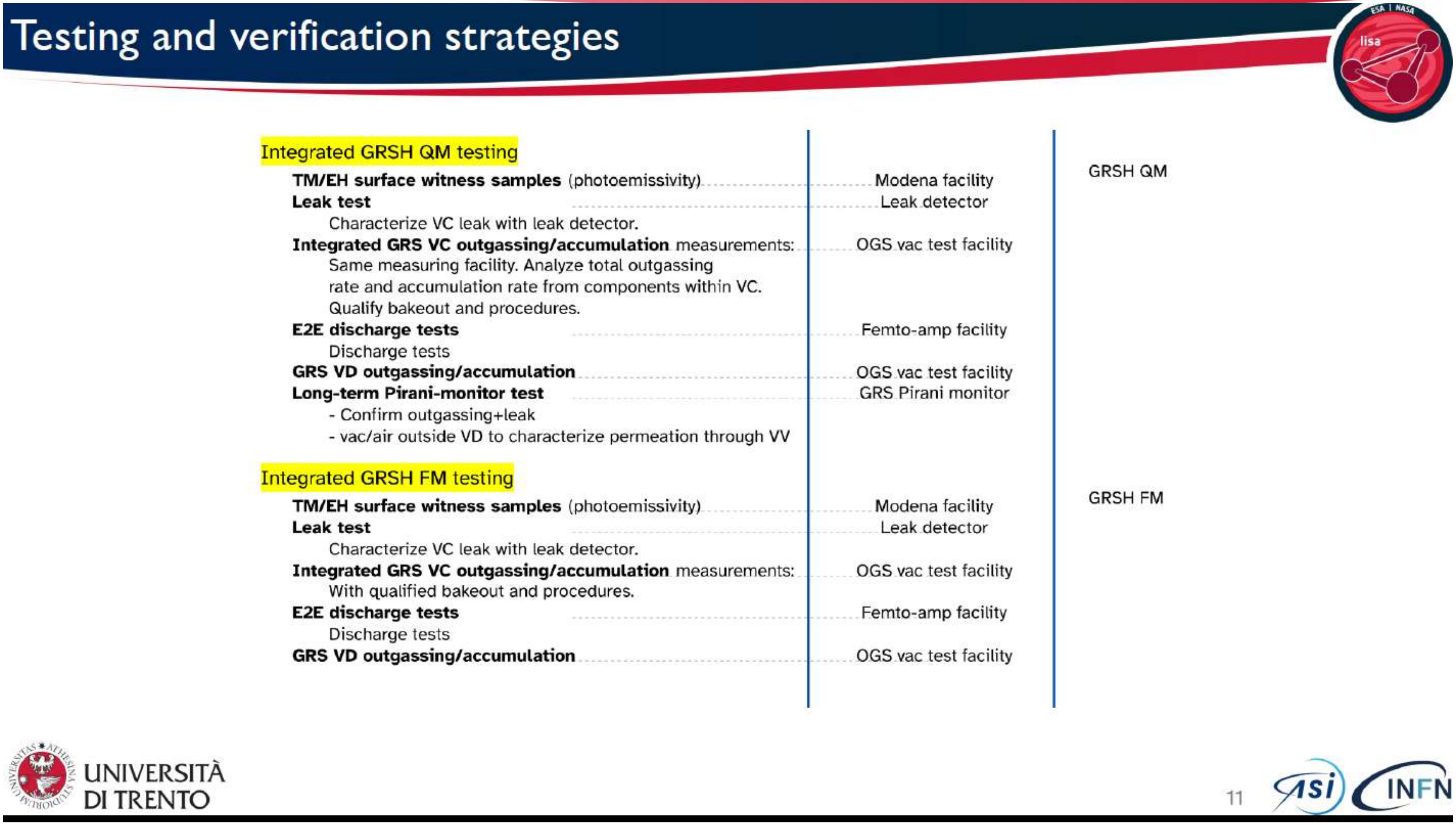


Testing and verification strategies (TN 0030)

	Test definition	Measurement Facility	Models
	Preliminary tests, characterization and modeling:		
	Individual outgassing rate measurements: Cables (PFA/PTFE), connectors (PEEK), other plastics, inner VC surfaces, EH surfaces, W/Cu IBM, GPRM, CVM, other items of interest TBD. Compare baked vs non-baked items.	OGS vac test facility	Samples, Equipment EMs, LPF QMs
	Individual accumulation rate measurements: Same units under test, analyze accumulation.		
Pre-bake polymers	**Bakeout test for cables and other TBD items** Analyze volatile composites emitted by cables during bakeout and establish pre-integration bakeout strategy (plastics could need pre-baking before integration)	CVCM TBD facility	
Analyze the effect of bakeout on UV yield	**TM/EH gold surface tests (pre/post bakeout)** Photoemissivity + work function + ...	Modena facility	
	Integrated GRSH EM testing		
	Integrated GRS VC outgassing/accumulation measurements: Same measuring facility, design a "GRS VGSE cap" attachable to measuring facility. Analyze total outgassing rate and accumulation rate from components within VC. Analyze effect of bakeout and consolidate procedures.	OGS vac test facility	EM EH with cables, dummy TM with EM coating, representative VC+IBM, passive GPRM (LPF TBC), representative VC items, Pirani monitor
	E2E discharge tests Discharge tests on equipment EM + LPF QM	Femto-amp facility	
	GRS VD outgassing/accumulation	OGS vac test facility	
	Leak test Characterize VC leak with leak detector.	Leak detector	
	Long-term Pirani-monitor test - Confirm outgassing+leak, - vac/air outside VD to characterize permeation through VV	GRS Pirani monitor	

10

UniTN support to EM End2End Testing @ OHB I



Testing and verification strategies

Integrated GRSH QM testing		GRSH QM
TM/EH surface witness samples (photoemissivity)	Modena facility	
Leak test Characterize VC leak with leak detector.	Leak detector	
Integrated GRS VC outgassing/accumulation measurements: Same measuring facility. Analyze total outgassing rate and accumulation rate from components within VC. Qualify bakeout and procedures.	OGS vac test facility	
E2E discharge tests Discharge tests	Femto-amp facility	
GRS VD outgassing/accumulation	OGS vac test facility	
Long-term Pirani-monitor test - Confirm outgassing+leak - vac/air outside VD to characterize permeation through VV	GRS Pirani monitor	
Integrated GRSH FM testing		GRSH FM
TM/EH surface witness samples (photoemissivity)	Modena facility	
Leak test Characterize VC leak with leak detector.	Leak detector	
Integrated GRS VC outgassing/accumulation measurements: With qualified bakeout and procedures.	OGS vac test facility	
E2E discharge tests Discharge tests	Femto-amp facility	
GRS VD outgassing/accumulation	OGS vac test facility	

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11

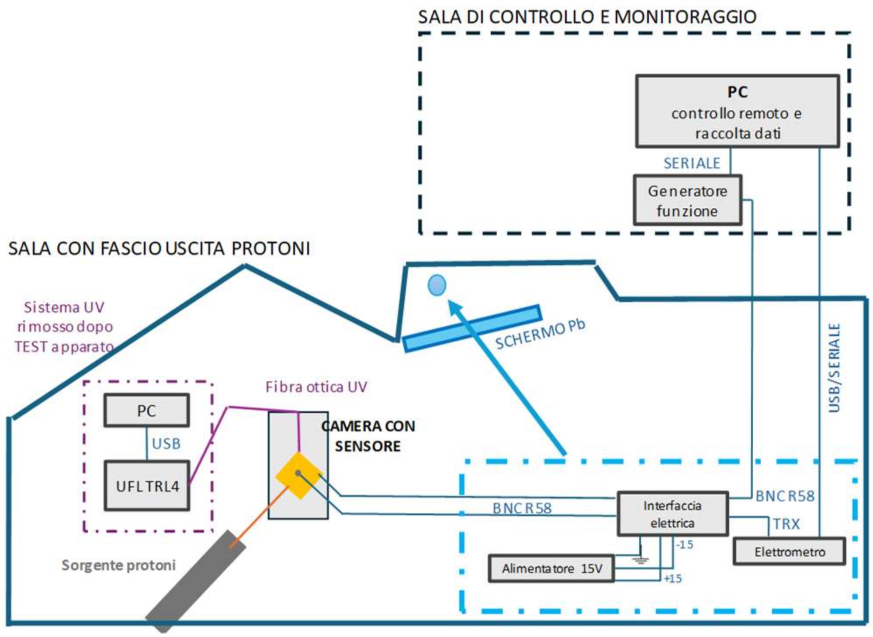
TM charging with proton beam

The significant difference between the actual TM charging values expected from early simulation studies and those measured aboard LPF was attributed to the lack of LEE production models(ESA contract No. 4000133571/20/NL/CRS “Test Mass Charging Toolkit and LPF Lessons Learned” with OHB-I, and University of Urbino C.Grimani)

BART: experimental verification that the interaction of high-energy charged particles from cosmic ray interaction cascades with S/C materials around the TM creates a cloud of very low energy electrons (eV) in the gap between TM and EH.

Test execution upcoming

F.Dimiccoli, F. Venturelli, T. Klaser, A.Cavalleri, D.Dal Bosco, V.Ferroni



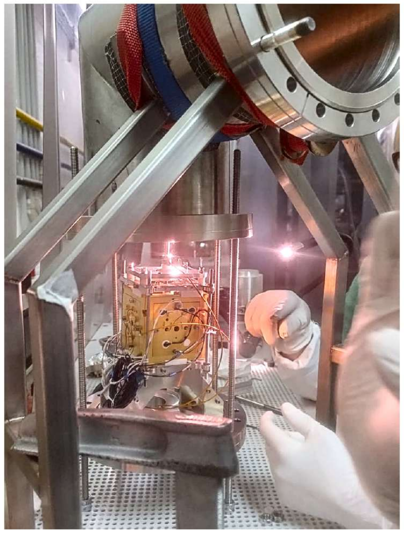


Figura 29: Integrazione del sensore all’interno della camera da vuoto di BART

Beam-like Application of Radiation on Test-masses

Assegnazioni 2024-25 e Preventivi 2026

- La maggior parte delle richieste fatte per il 2025 ci sono state assegnate in anticipo nel 2024 e i relativi ordini sono stati portati a termine(100 k€)
- Disponiamo ancora di 60k€ SJ per Test Mass per i test con i pendoli +16k€ di manutenzione e strumenti

- Per il 2026 le richieste dovrebbero essere contenute, 50 k€+ missioni

ANAGRAFICA 2025

Nome Cognome	Contratto	Qualifica	Ente	% LISA CSN2	Impegni in altre sigle	Pagati su fondi	Commenti
TRENTO							
Ayele Gelan Abraham	Associato	dottorando	UniTN	**100**			
Bortoluzzi Daniele	Associato	Prof. Ordinario	UniTN	**50**			
Cavalleri Antonella	Associato	Ricercatore Confermato	CNR/FBK	**100**		CNR/FBK	
Chiavegato Vittorio	Associato	dottorando	UniTN	**100**			
Dal Bosco Davide	Associato	Assegnista di Ricerca	UniTN	**100**		ASI	
Dimiccoli Francesco	Associato	Ric Tempo Det Tipo A	UniTN	**100**		ASI	
Dolesi Rita	Associato	Prof. Associato	UniTN	**100**			
Ferroni Valerio	Associato	Tecnologo E.P.	UniTN	**100**		ASI	
Marzari Francesco	Associato	dottorando	UniTN	**100**			
Teodoro Klaser	Associato	Assegnista di Ricerca	UniTN	**100**		ASI	
Tommasi Matteo	Associato	dottorando	UniTN	**100**		OHB LISA (GPRM EM)	
Sala Lorenzo	Associato	Assegnista di Ricerca	UniTN	**100**		ASI	
Venturelli Francesco	Associato	dottorando	UniTN	**100**			
Vetrugno Daniele	Associato	Tecnologo E.P.	UniTN	**100**		ASI	
Vitale Stefano	Associato	Prof. Senior	UniTN	**0**			OVER 70
Weber William	Associato	Prof. Associato	UniTN	**100**			
Zanoni Carlo	Dipendente	Primo tecnologo	INFN	**100**		ASI	previsto rinnovo di 2 anni dal 1-12-24
			TOT FTE	**15,5**			

- Daniele Vetrugno

+ Giacomo Ciani 60%